

SECTION 8.0 GROUNDWATER

The assessment of groundwater conditions at the Refinery has been based primarily on data collected from 120 monitoring wells. Two rounds of groundwater samples have been collected from these wells; Round One during the fourth quarter of 2002 and Round Two during the first six months of 2003. The data collected includes laboratory analytical results for the presence of VOCs, SVOCs, metals and TICS. The data also includes groundwater elevations and the results of analyses conducted on groundwater samples collected from temporary wells during previous investigations.

From a site-wide perspective, the results of this study have provided sufficient information to develop a comprehensive model of the shallow groundwater conditions at the Refinery including the hydrogeological setting and the distribution of COCs. In general, the surficial geology of the site consists of two to 20 feet of miscellaneous fill overlying native materials. The native materials immediately beneath the fill consist of a reddish-brown till and gray organic clays (Clay Horizon A) that are sometimes capped by a layer of peat. The peat is primarily located in the northern and eastern portions of the site. The shallow water table has been found to be perched on this fill/native interface over much of the Refinery. The till and the organic clays have each been shown to be as much as 40 feet thick in various locations at the Refinery. At some locations, a discontinuous sand (Sand Horizon A) is encountered at the base of Clay Horizon A. This sand ranges from two to 10 feet in thickness and contains varying levels of silt and clay.

Based on past investigation, it is known that beneath the surficial native materials lies the Woodbridge Clay (Clay Horizon B), described as a gray, sandy or silty, stiff clay. This unit has been shown to be from 10 to 40 feet thick. The Farrington Sand lies beneath the Woodbridge Clay at depths ranging from 50 feet bgs to more than 80 feet with thicknesses of up to 50 feet.

Refinery-wide groundwater flow has been confirmed in a north to northeasterly direction with a few variations. The gradients that have been measured range from a high of 0.02 to less than 0.001. The average gradient appears to be approximately 0.01. The materials that make up the fill are described as a mix of sands, silts and clays that, taken as a whole, have an estimated hydraulic conductivity of 1×10^{-4} cm/sec. This estimate is supported by studies conducted in previous investigations conducted at the Refinery such as the Phase I and Phase II hydrogeologic studies by Woodward-Clyde Consultants (1981 and 1982a). The characteristics of the fill material and the low gradients result in fairly low seepage velocities for the shallow water table. This indicates limited movement of the groundwater and migration of constituents found within the site boundaries.

While several areas of groundwater impacted by dissolved phase constituents have been identified within the Refinery, data from the sentinel well system indicates that the perimeter of the site, with the possibility of one exception, is not impacted by these constituents.

The presentation of the data has been divided into three main geographic sections: the East Yard, the North Field/Main Yard and the Central Yard. For each geographic section, the area-specific geology and hydrogeology are described and the results of the groundwater analysis are presented. A summary and analysis of the data is provided and areas impacted by COCs are identified, evaluated and delineated.

8.1 East Yard

The assessment of the East Yard groundwater conditions is based on data collected from a total of 54 wells that were installed as part of the RFI or previous investigations. For the purposes of this report, the property between the rail line and State Street (State Street parking lot and the loading rack) has been included as part of the East Yard. The wells used in the assessment of groundwater in the East Yard are shown on Figure 8-1. They include the following:

- Pre RFI wells – 10 shallow and 2 deep wells;
- Closure Wells – 4 shallow wells;
- LNAPL Investigation wells – 13 shallow wells; and
- RFI Wells – 24 shallow and 1 deep well.

The deep wells consist of P-7, P-3 and MW-178. These wells are screened in the first water bearing zone beneath the fill/native interface. Together, the shallow and deep wells provide a comprehensive monitoring network for the East Yard. Two rounds of water level measurements have been collected as well as two rounds of groundwater samples from most wells. This section will discuss the surficial geology of the East Yard, the results of the groundwater investigation and the distribution of contaminants in the East Yard groundwater.

8.1.1 Geology

In general, the East Yard is composed of varying amounts of fill overlying a discontinuous peat layer, gray clay (Clay Horizon A) and glacial till. The data shows that the top of the water table is in the fill layer. The fill contains varying amounts of sand, gravel and debris, but is primarily composed of silts and clays. Four cross sections (Figures 8-2 through 8-5) are provided which show the variable thicknesses and content of the fill material throughout the Yard. The location of each cross section is shown on Figure 8-1.

The silty clay fill is evident in the bulk of the East Yard except in a narrow strip along the bulkhead on the northern half of the eastern boundary of the Yard. In the 1970's, Chevron constructed a bulkhead along the Arthur Kill. For structural support, well-sorted, coarse grain sand was used as backfill. The sand extends up to 100 feet west from the Arthur Kill and to depths reaching 30 feet bgs. Figure 8-5 shows the extent of the sand in a north-south direction. This sand is an important feature for monitoring groundwater at the eastern edge of the East Yard.

Beneath the fill, a native clay (Clay Horizon A) covered by a discontinuous peat layer is found. The clay is of variable thickness, up to 30 feet in some areas. Discontinuous sand lenses are found near the base of the clay at depths ranging from 15 to 25 feet below grade. These sands are the stratigraphic equivalent of Sand Horizon A. The sands appear to be truncated and only exist in the central and western portions of the East Yard.

In some areas, glacial till may be found at the base of the fill as shown in Figure 8-4. The till appears as a reddish-brown silt with varying amounts of clay, sand and gravel.

Beneath the till and Clay Horizon A is clay Horizon B, the Woodbridge Clay. Borings conducted in previous investigations have shown this clay to be from 20 to 30 feet thick in the East Yard.

Earlier investigations (Woodward Clyde Associates, 1982) have shown the Farrington Sand beneath the Woodbridge Clay at depths of 60 feet. It has also been shown that the Farrington Sand is not continuous and does not exist beneath the eastern portions of the East Yard.

8.1.2 Hydrogeology

The shallow groundwater in the East Yard is found unconfined in the fill material, perched on the native clay, peat and till. On June 23, 2003 groundwater elevations were measured in 53 of the 54 wells. The results of this elevation data is presented in Figure 8-1. As shown, groundwater generally flows in a northeasterly direction from a high at MW-129 (State Street parking lot) of 24.72 feet above mean sea level (MSL) to a low near the East Yard Basin of 2.78 feet above MSL in MW-175. The data shows a “ridge” of groundwater trending east-west through the central portion of the East Yard. This ridge causes a somewhat radial flow pattern in the eastern portion of the Yard. The cross sections in Figures 8-3 and 8-4 show that this ridge is due to perched water on Clay Horizon A and till deposits.

Gradients measured across the East Yard vary to some extent but approximate 0.01 feet/foot (ft/ft). Gradients representative of the overall site conditions are provided in Table 8-1.

Table 8-1. East Yard Gradients

Well	Well	Distance (feet)	Elevation Change (feet)	Gradient (ft/ft)
MW-157	MW-173	1,125	11.30	0.01
MW-14	MW-173	1,200	11.93	0.01
MW-142	MW-156	945	13.08	0.014
MW-142	MW-175	650	14.19	0.022

As part of the 1982 hydrogeologic study of the Refinery conducted by Woodward Clyde Associates, several tests of horizontal permeability were conducted.

Falling head or slug tests were conducted on wells SB-10, SB-11, SB-12, SB-13A, SB-13B and DMS-5. The results indicated hydraulic conductivity ranging from 4×10^{-5} cm/sec to 4×10^{-6} cm/sec for wells screened across the fill layer, Sand Horizon A, Clay Horizon A and the till.

Vertical permeabilities were also measured in SB-12 and SB-13A as part of the Woodward Clyde investigations. Both wells are screened in the till zone and laboratory analysis shelly tube samples indicate vertical permeabilities of approximately 6×10^{-8} .

Since the majority of shallow fill materials found in the East Yard consists of silts and clays with some sand similar to those areas tested by Woodward Clyde Associates, an average hydraulic conductivity of 1×10^{-4} cm/sec has been selected as representative of the site conditions. Chevron feels this is a conservative number considering the results of the tests conducted by Woodward Clyde Associates.

Published values (Fetter, 1988) have been used to estimate effective porosity of unconsolidated materials similar to the East Yard fill. The estimates of conductivity and effective porosity and the measured gradients have been used to determine estimated seepage velocities for groundwater in the vicinity of the dissolved contaminant plumes found in the East Yard. The published values used are presented in Table 8-2.

Table 8-2. East Yard Soil Parameters

Fill Material	Estimated Hydraulic Conductivity	Estimated Effective Porosity
Sand	1×10^{-2} cm/sec	25%
Silty Sand, Fine Sand	1×10^{-3} cm/sec	20%
Silt, Sandy Silt, Clayey Sand	1×10^{-4} cm/sec	15%
Silty Clay	1×10^{-5} cm/sec	12%
Clay	1×10^{-6} cm/sec	10%

In general, seepage velocities of groundwater have been found to be extremely low due to low gradients and the limited permeabilities of the fill material. The fill material in which the shallow groundwater resides is primarily made up of silts and clays that have limited permeabilities and restrict groundwater flow.

It must be noted that the seepage velocities presented are not rates of transport for contaminants as they don't account for retardation and degradation. The need to calculate rates of transport will be determined subsequent to the collection of additional analytical data.

8.1.3 Groundwater Chemistry

8.1.3.1 Contaminant Distribution – First Round

During the fourth quarter of 2002, a round of groundwater samples was collected from the existing East Yard monitoring well system. A total of 34 wells were sampled during

this period. Of these, groundwater samples from 29 wells were analyzed for RFI parameters including VOCs (SW-846 8260), SVOCs (SW-846 8270) and metals. Also included were tests for alkalinity, hardness, chlorides, sulfates, nitrites, nitrates and TDS. Of the remaining five wells, samples from two (MW-155 and MW-156) were analyzed for VOCs and SVOCs only, and samples from three wells (SB-14, SB-15 and SB-17) were analyzed for closure parameters (a limited list of VOCs and SVOCs). A library search for TICs was conducted for all 34 samples.

VOC Results

VOCs were detected above the delineation criteria (NJDEP Class IIA GWQC) in 11 of the 34 wells sampled (Figure 8-6). Benzene was included in all 11 detections. In fact, benzene was the only VOC detected above the delineation criteria in nine of the 11 wells. The two wells that exhibited detections of compounds other than benzene above the delineation criteria were MW-132 and RW-61 (Table 8-3).

Table 8-3. East Yard First Round VOC Results

Compounds (results in µg/L)	MW-132	RW-61
Benzene (Criterion = 1 µg/L)	700	2,000
Toluene (Criterion = 700 µg/L)	NE	2,900
Xylene (Criterion = 1,000 µg/L)	NE	2,900
1,2,Dibromoethane (Criterion = 0.05 µg/L)	NE	5
Chlorobenzene (Criterion = 4 µg/L)	580	NE
Cyclohexane (Criterion = 100 µg/L)	150	NE
1,4,Dichlorobenzene (Criterion = 75 µg/L)	250	NE
Methylcyclohexane (Criterion = 100 µg/L)	100	NE

NE Does not exceed criterion

MW-132 was placed in the center of a potential TEL burial (SWMU 8) and RW-61 was originally installed near the Crude Slab to recover LNAPL. These results will be examined further in the discussions specific to these areas, below.

SVOC Results

SVOCs were detected in excess of the delineation criteria in four of the 34 wells sampled during the fourth quarter of 2002 (Figure 8-8). Of the four detections, only two were petroleum-related compounds. The phthalates detected in MW-152 are common contaminants associated with sample handling procedures and are not evaluated further. Nitrosodiphenylamine (79 µg/L), detected in MW-129, is an uncommon contaminant,

and its presence needs to be confirmed through additional sampling. Based on the infrequency of detection and lack of relationship to the site operations, this constituent is not evaluated further.

Petroleum-related SVOCs were detected in MW-156 and MW-132. The apparent groundwater impacts in MW-132 are associated with the TEL burial at SWMU 8. These compounds included dimethylphenol (160 µg/L), naphthalene (310 µg/L) and 2-methylnaphthalene (180 µg/L). In the groundwater sample from MW-156, naphthalene (470 µg/L) and carbazole (11 µg/L) were detected. These compounds are associated with the asphaltic material in the 5 Berth area that has been identified as AOC 29.

Metals Results

Metals were detected in the majority of the wells in the East Yard in excess of the groundwater delineation criteria. These included naturally-occurring iron, manganese and to a lesser extent, aluminum. The presence of these metals in the groundwater is attributed to the clays that are included in the fill material and the native soil. Chevron does not consider these analytes to be COCs and they will not be included in further evaluations of the East Yard groundwater.

Detections of other metals in the fourth quarter of 2002 sampling were sporadic (Figure 8-9). Of the 29 wells sampled for metals, 17 had detections in excess of the delineation criteria. The analyte most often encountered was arsenic. Arsenic was detected above the delineation criteria in 11 wells ranging in concentration from 9.9 to 408 µg/L. In addition, exceedances of lead were detected in four wells, cobalt and thallium in two wells and nickel and antimony exceeded the delineation criteria in one well each (Table 8-4).

Tentatively Identified Compounds

Of the 34 wells sampled during the fourth quarter of 2002, groundwater from 33 was analyzed for TICs. The initial review of the TIC data indicated that 4-hydroxy-4-methyl-2-pentanone was commonly identified. Upon discussions with the laboratory, it was determined that this compound is a condensation product created in the laboratory during the sample extraction procedure. Therefore, this compound is not included in the following evaluation.

Tentatively identified VOCs were found in nine of the 33 samples (Table 8-5). Of these, eight were associated with wells where benzene exceedances had been detected. Because these TICs are collocated with targeted constituents that will be addressed as part of the RFI and CMS processes, no further evaluation was conducted. MW-151 did not contain any of the targeted volatile compounds, but two TICs were identified at 8 µg/L each. These were described in the lab report as an aromatic compound and an alcohol and did not exceed the interim generic criteria of 100 µg/L.

Table 8-4. East Yard Metals Data (µg/L)

Well	Arsenic (Criterion = 8 µg/L)		Lead (Criterion = 10 µg/L)		Cadmium (Criterion = 4 µg/L)		Cobalt (Criterion = 100 µg/L)		Nickel (Criterion = 100 µg/L)		Thallium (Criterion = 10 µg/L)	
	Round 1	Round 2	Round 1	Round 2	Round 1	Round 2	Round 1	Round 2	Round 1	Round 2	Round 1	Round 2
A21TP1	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	126	99
MW-006	NE	NE	NE	NE	NE	NE	143	139	167	171	NE	NE
MW-007	408	115	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
MW-008	14.9	NE	NE	NE	NE	5.8J	NE	NE	NE	NE	NE	NE
MW-009	NE	NE	40.6	59.7	NE	27.6	NE	NE	NE	NE	NE	NE
MW-010	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
MW-014	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
MW-035	NE	NE	NE	31	NE	NE	NE	NE	NE	NE	NE	NE
MW-043	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
RW-061	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
MW-090	NS	17	NS	NE	NS	NE	NS	NE	NS	NE	NS	NE
MW-090	NS	17.7	NS	NE	NS	NE	NS	NE	NE	NE	NE	NE
MW-105	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
MW-129	297	125	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
MW-131	20.7	NE	15.5J	NE	NE	NE	NE	NE	NE	NE	NE	NE
MW-131	11	9.6J	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
MW-132	37.2	30	172	130	NE	NE	NE	NE	NE	NE	NE	NE
MW-134	NE	NE	NE	10.5J	NE	NE	NE	NE	NE	NE	NE	NE
MW-135	9.9J	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
MW-141	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
MW-142	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
MW-143	104	56.8	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
MW-144	81.7	53	NE	NE	NE	NE	NE	NE	NE	NE	67.1	NE
MW-145	NE	NE	NE	NE	NE	NE	121	NE	NE	NE	NE	NE
MW-146	79.2	19.4	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
MW-148	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
MW-149	41.1	28.1	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
MW-150	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
MW-151	NE	NE	NE	12.4	NE	NE	NE	NE	NE	NE	NE	NE
MW-152	26.6	24	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
MW-153	NE	NE	19.7	NE	NE	NE	NE	NE	NE	NE	NE	NE
MW-155	NS	8.4	NS	NE	NS	NE	NS	NE	NS	NE	NS	NE
MW-156	NS	14	NS	NE	NS	5.8J	NS	NE	NS	NE	NS	NE
MW-157	NS	NE	NS	40.4	NS	8J	NS	NE	NS	NE	NS	NE
MW-158	NE	13	NE	NE	NE	5.2J	NE	160	NE	190	22.4	75

Table 8-4. East Yard Metals Data (µg/L)

Well	Arsenic (Criterion = 8 µg/L)		Lead (Criterion = 10 µg/L)		Cadmium (Criterion = 4 µg/L)		Cobalt (Criterion = 100 µg/L)		Nickel (Criterion = 100 µg/L)		Thallium (Criterion = 10 µg/L)	
	Round 1	Round 2	Round 1	Round 2	Round 1	Round 2	Round 1	Round 2	Round 1	Round 2	Round 1	Round 2
MW-171	NS	NE	NS	NE	NS	NE	NS	NE	NS	NE	NS	NE
MW-172	NS	NE	NS	NE	NS	NE	NS	NE	NS	NE	NS	NE
MW-173	NS	13.6	NS	NE	NS	NE	NS	NE	NS	NE	NS	NE
MW-174	NS	12	NS	NE	NS	NE	NS	NE	NS	NE	NS	NE
MW-175	NS	NE	NS	NE	NS	NE	NS	NE	NS	NE	NS	NE
MW-178	NS	NE	NS	NE	NS	NE	NS	NE	NS	NE	NS	NE
SB-14	NS	NE	NE	NE	NE	NE	NS	NS	NS	NE	NS	NS
SB-15	NS	NE	NE	NE	NE	NE	NS	NS	NS	NE	NS	NS
SB-17	NS	NE	NE	NE	NE	NE	NS	NS	NS	NE	NS	NS

Exceeds one or more criteria

NS Not sampled

NE Does not exceed criterion

Table 8-5. East Yard Benzene and TIC Data (µg/L)

Well	Round 1							Round 2						
	Benzene	VOC TICs			SVOC TICs			Benzene	VOC TICs			SVOC TICs		
		No.	Single	Total	No.	Single	Total		No.	Single	Total	No.	Single	Total
A21TP1	NE	0	0	0	20	60	407	NE	4	9	24	19	16	137
MW-006	47	0	0	0	2	12	20	23	0	0	0	3	10	21
MW-007	NE	0	0	0	1	7	7	NE	0	0	0	4	24	47
MW-008	NE	0	0	0	5	17	58	NE	0	0	0	2	68	118
MW-009	NE	0	0	0	1	5	5	NE	0	0	0	0	0	0
MW-010	NE	0	0	0	1	12	12	NE	0	0	0	2	7	11
MW-014	NE	0	0	0	2	20	40	NE	0	0	0	0	0	0
MW-035	NE	0	0	0	1	34	34	NE	0	0	0	2	11	16
MW-043	NE	0	0	0	1	13	13	NE	0	0	0	3	6	17
MW-105	NE	0	0	0	11	100	185	NE	0	0	0	9	56	130
MW-129	NE	0	0	0	11	42	150	NE	0	0	0	4	28	52
MW-131	180	10	70	358	20	66	843	1,100	10	170	1,169	20	110	1,482
MW-131	NS	NS	NS	NS	NS	NS	NS	870	10	77	492	20	110	1480
MW-132	700	10	54	260	20	320	2,249	900	10	130	620	19	44	378
MW-134	8	10	210	1,138	20	62	533	6	10	120	598	20	160	1,271
MW-135	3	0	0	0	15	26	114	38	3	13	29	19	36	198
MW-141	29	0	0	0	0	0	0	9	0	0	0	2	92	97
MW-142	NE	0	0	0	20	10	139	NE	0	0	0	7	10	42
MW-143	NE	0	0	0	5	16	52	NE	0	0	0	0	0	0
MW-144	NE	0	0	0	12	44	133	NE	0	0	0	7	44	102
MW-145	NE	0	0	0	4	60	82	NE	0	0	0	3	53	70
MW-146	100	10	180	1,171	20	1,000	7,470	48	10	100	508	20	170	793
MW-148	NE	0	0	0	1	13	13	NE	0	0	0	2	7	11
MW-149	9	10	59	373	20	50	483	8	10	33	212	20	28	205
MW-150	NE	0	0	0	6	36	67	NE	0	0	0	4	18	50
MW-151	NE	2	8	16	14	110	200	NE	1	7	7	13	100	197
MW-152	NE	0	0	0	4	37	58	NE	0	0	0	1	5	5
MW-153	NE	0	0	0	1	4	4	NE	0	0	0	3	11	26
MW-155	2	10	53	387	20	50	461	NE	10	39	242	20	28	253
MW-156	4	10	55	228	20	49	317	2J	10	35	172	20	46	271
MW-157	NS	NS	NS	NS	NS	NS	NS	4J	4	8	23	4	47	64
MW-158	NE	0	0	0	13	18	121	NE	0	0	0	17	22	129
MW-171	NS	NS	NS	NS	NS	NS	NS	3,600	10	1,400	6,350	20	570	2,974
MW-171	NS	NS	NS	NS	NS	NS	NS	NE	1	6	6	0	0	0

Table 8-5. East Yard Benzene and TIC Data (µg/L)

Well	Round 1							Round 2						
	Benzene	VOC TICs			SVOC TICs			Benzene	VOC TICs			SVOC TICs		
		No.	Single	Total	No.	Single	Total		No.	Single	Total	No.	Single	Total
MW-172	NS	NS	NS	NS	NS	NS	NS	NE	0	0	0	1	9	9
MW-173	NS	NS	NS	NS	NS	NS	NS	NE	0	0	0	5	10	31
MW-174	NS	NS	NS	NS	NS	NS	NS	NE	0	0	0	0	0	0
MW-175	NS	NS	NS	NS	NS	NS	NS	NE	0	0	0	0	0	0
MW-178	NS	NS	NS	NS	NS	NS	NS	NE	0	0	0	0	0	0
RW-61	2,000	10	110	482	20	450	1,916	NS	NS	NS	NS	NS	NS	NS
SB-14	NE	NS	NS	NS	3	24	50	NE	0	0	0	0	0	0
SB-15	NE	NS	NS	NS	0	0	0	NE	1	13	13	17	13	102
SB-17	NE	NS	NS	NS	3	18	46	NE	0	0	0	0	0	0

Exceeds benzene criterion (1 µg/L)

Contains TICs that are unknown and exceed the interim generic standard for individual TICs (100 µg/L) or total TICs (500 µg/L)

Contains TICs that have a CAS # and exceed one or more criteria

Tentatively identified SVOCs were detected in 31 of 33 groundwater samples. Of the 31:

- Ten were from wells where benzene had been detected in excess of the delineation criteria and were not evaluated further since benzene will serve as a surrogate.
- Twenty groundwater samples had TICs that were detected below the NJDEP Interim Criteria of 100 µg/L for individual organic compounds and 500 µg/L for total combined organic compounds.
- One sample contained a compound tentatively identified as aniline which has an interim specific criterion of 6 µg/L.

8.1.3.2 Contaminant Distribution – Second Round

Based on the assessment of the fourth quarter 2002 groundwater data, Chevron installed an additional six wells in the East Yard. A second round of groundwater sampling and analysis was conducted to confirm the results of the initial effort. The sampling was conducted during the first six months of 2003 and included all the wells sampled during the fourth quarter 2002 round (except RW-61), two additional existing wells and the six new wells for a total of 41 wells.

Of these, groundwater samples from 38 wells were analyzed for RFI parameters including VOCs (SW-846 8260), SVOCs (SW-846 8270) and metals. Also included were analyses for alkalinity, hardness, chlorides, sulfates, nitrites, nitrates and TDS. The remaining three wells (SB-14, SB-15 and SB-17) were analyzed for closure parameters (a limited list of volatile and semi-volatile compounds).

VOC Results

VOCs were detected above the groundwater delineation criteria in 11 of the 41 wells sampled (Figure 8-7). Benzene was included in all 11 detections. Benzene was the only VOC detected above the delineation criteria in seven of the 11 wells. Wells indicating the presence of other VOCs included MW-132, MW-131, MW-135 and MW-90 (Table 8-6). Compounds worth noting include methyl tert-butyl ether that was detected at 71 µg/L in MW-135. This compound was never used at the Refinery and its presence must be attributable to other sources.

Table 8-6. East Yard Second Round VOC Results

Compounds (results in µg/L)	MW-90		MW-131		MW-132	MW-135
Benzene (Criterion = 1 µg/L)	3,600	6,300	870	1,100	900	38
Ethylbenzene (Criterion = 700 µg/L)	830	960	NE	NE	NE	NE
Toluene (Criterion = 1,000 µg/L)	NE	NE	NE	NE	NE	NE

Table 8-6. East Yard Second Round VOC Results

Compounds (results in µg/L)	MW-90		MW-131		MW-132	MW-135
Xylene (Criterion = 1,000 µg/L)	2,300	2,700	NE	NE	1,200	NE
1,2,Dibromoethane (Criterion = 0.05 µg/L)	NE	NE	NE	NE	NE	NE
Chlorobenzene (Criterion = 4 µg/L)	NE	NE	NE	NE	210	NE
Cyclohexane (Criterion = 100 µg/L)	420	440	150	150	250	NE
1,4,Dichlorobenzene (Criterion = 75 µg/L)	NE	NE	NE	NE	NE	NE
Methylcyclohexane (Criterion = 100 µg/L)	250	260	NE	NE	210	NE

Ten of the 11 benzene detections above criteria in the first round were confirmed by the second round data. Only one exceedance (2 µg/L) in MW-155 was not confirmed. Another well, RW-61 (2,000 µg/L), was not re-sampled. However; the periodic presence of LNAPL in this well is considered confirmation of the petroleum contamination. Of the ten confirmed exceedances of benzene, results from six wells indicated decreasing concentrations and three wells showed increasing concentrations (MW-135, MW-132 and MW-131). As stated, RW-61 was not sampled due to the presence of LNAPL. Benzene was also detected above the criterion in two wells not sampled during the fourth quarter of 2002 (MW-90 and MW-157).

SVOC Results

SVOCs were detected in excess of the groundwater delineation criteria (NJDEP Class IIA GWQC) in five of the 41 wells sampled during the fourth quarter of 2002 (Figure 8-8). Of the five exceedances, four included petroleum-related compounds. The detection of phthalates in MW-152 during the fourth quarter of 2002 was not confirmed. However, the detection of nitrosodiphenylamine in MW-129 (35 µg/L) was repeated. Other detections in excess of the delineation criteria included:

- Pentachlorophenol (14 µg/L) in MW-131;
- Estimated levels of benzo(a)pyrene (1 µg/L) and benzo(b)anthracene (2 µg/L) in MW-146;
- Naphthalene in MW-156 (470 µg/L); and
- Dimethylphenol in MW-132 (200 µg/L).

The detections in MW-132 and MW-156 are confirmations of the results of the fourth quarter 2002 data. However, the SVOCs identified in MW-146 and MW-131 were not confirmed in the fourth quarter 2002 sampling.

Metals Results

Similar to the first sampling round, detections of metals in the second round of samples (first half of 2003) above criteria were sporadic (Figure 8-9). Of the 38 wells sampled for metals, 21 had detections in excess of one or more delineation criteria (Table 8-4).

The analyte most often encountered was arsenic. Arsenic was detected in excess of the criterion in 14 wells ranging in concentration from 12 to 125 µg/L. Of the previous ten arsenic exceedances in the first sampling round, eight were confirmed by the second round samples. Exceedances were not confirmed in two wells (MW-8 and MW-135). Arsenic was detected in MW-135, but it was an estimated value below the criterion. In the second sampling round, arsenic exceedances were detected in six additional wells. However, only one of these wells had previously been sampled for arsenic (MW-158). In the first sampling round, arsenic was detected at an estimated value below the criterion in MW-158.

Lead was the second most common metal detected (six wells) in excess of the criterion. Two exceedances of lead in the fourth quarter 2002 round of samples (MW-132 and MW-9) were confirmed in the second round. The exceedance of lead in MW-153 in the first round was not confirmed in the second round. In addition, a lead exceedance was found for the first time in:

- MW-134 at an estimated value of 10.4 µg/L;
- MW-35 at 31 µg/L; and
- MW-151 at an estimated value of 12.4 µg/L.

Lead was also detected in MW-157 (40.4 µg/L), sampled for the first time. Other detections of metals in excess of the criteria included five wells with cadmium, two with cobalt, two with nickel and one with thallium.

Tentatively Identified Compounds

Groundwater was analyzed for TICs from the 41 wells sampled in the East Yard as part of the second round. As before, the compound 4-hydroxy-4-methyl-2-pentanone was detected in numerous samples and is not included in further evaluation of the TICs as it is a laboratory artifact.

Tentatively identified VOCs were found in 14 of the 41 samples (Table 8-5). Of these, ten were associated with wells where benzene exceedances had been detected. No further evaluation was conducted since benzene would serve as a surrogate for these VOC TICs. An additional three samples contained VOC TICs at levels below the NJDEP Interim Generic Organic Criterion of 100 µg/L and the Combined Total Organic Criterion of 500 µg/L. SB-15 did not contain any of the targeted VOCs. One TIC (2-methoxy-2-methylpropane, CAS# 1634-04-4) was identified, but the concentration (13 µg/L) was below the NJDEP Interim Organic Criterion of 100 µg/L.

Tentatively identified SVOCs were detected in 32 of 41 groundwater samples. Of the 32:

- Twelve were from wells where benzene had been detected in excess of the delineation criteria and were not evaluated individually since benzene would serve as their surrogate.
- Eighteen TICs were without CAS numbers and were detected below the NJDEP Interim Generic Organic Criterion of 100 µg/L for individual compounds and 500 µg/L for total combined organic compounds.
- Two samples had TICs with CAS numbers included. There was no evidence of carcinogenicity for these compounds and they did not exceed the Interim Generic Organic Criterion of 100 µg/L or the delineation criteria.

8.1.4 Data Analysis

Based on the two rounds of groundwater sampling and analysis conducted to date, Chevron has determined that further assessment of the East Yard groundwater relating to VOCs and SVOCs should be focused on benzene as the primary COC. This determination has been made for the following reasons:

- Benzene is the most broadly distributed volatile compound;
- Benzene is a carcinogen with the most stringent delineation criteria of the compounds exceeding available criteria with the exception of 1,2-dibromoethane, which was only detected and exceeded criterion in one well;
- Other VOC exceedances were collocated with benzene exceedances;
- Petroleum-based SVOC exceedances were collocated in wells where benzene exceedances were found;
- Benzene is expected to be the focus of the CMS;
- Benzene is soluble in groundwater and its fate and transport characteristics are well known; and
- Benzene is representative of the light end of the refining process, the presence of which is consistent with the refining history of the Site.

The benzene exceedances of groundwater delineation criterion in the East Yard ranged from 2 to 3,600 µg/L. These exceedances appear to be associated with seven distinct and separate dissolved phase plumes. The boundaries of these plumes are presented in Figure 8-6. From west to east, the areas to be discussed are as follows:

- AOC 21 – Maurer Road excavation;
- AOC 27 - Tank 777 Pipeway and SWMU 10 - TEL Burial in Basin 771;
- SWMU 42 – Crude Slab;
- AOC 31 – Tank Basin 772 Pump Pad;

- AOC 26, AOC 14 – East Yard Bunker Slab;
- AOC 6, AOC 29 – Oily Fill Area; and
- SWMU 8 – TEL Burial.
- MW-6
- Historical Hydropunch Detections

The following sections provide detail concerning each of the identified dissolved phase plumes.

8.1.4.1 AOC 21 – Maurer Road Excavation

The plume in this study area is limited in extent as shown on Figure 8-6. The plume is defined by low-level benzene exceedances in MW-134 and MW-135 at concentrations of 8 and 3 µg/L, respectively. For the fourth quarter 2002 sampling round, these were the only VOC exceedances. Groundwater flow is to the northeast and downgradient migration is monitored by three wells (MW-35, MW-158 and MW-43). Upgradient monitoring is provided by the two inch well, A21TP1, located on Maurer Road.

The gradient in this area is approximately 0.01 ft/ft based on measurements of groundwater elevations in MW-134, MW-43 and MW-158 (Table 8-7).

Table 8-7. AOC 21 Groundwater Gradients

Well	Well	Distance (feet)	Elevation Change (feet)	Gradient (ft/ft)
MW-134	MW-43	330	3.54	0.01
MW-134	MW-158	440	5.17	0.011

The boring logs in this area indicate the fill primarily consists of silts and clays up to ten feet thick, underlain by peat and clay. The wells are screened in the shallow water zone in the fill.

During the fourth quarter 2002 sampling round, VOC exceedances were not detected in A21TP1, MW-43, MW-35 or MW-158. Prior to the sampling conducted for the RFI, an exceedance of the benzene delineation criteria had been recorded for MW-35 (90 µg/L). MW-158 was subsequently placed downgradient of MW-35 to provide additional monitoring coverage.

Additional delineation data is provided by a hydropunch sample HP0019 that was placed along State Street and was non-detect for benzene (the method detection limit (mdl) is 5 µg/L). This sample was collected as part of the 1st-Phase RFI for groundwater in 1998.

Following the fourth quarter 2002 sampling, the data was assessed to determine the need for additional monitoring in this area. No additional wells were proposed; however, additional sampling of existing wells was determined to be necessary. The second round

of groundwater sampling occurred during the first five months of 2003. Samples were collected from five of the six wells that are of interest in this area.

Benzene exceedances were confirmed in wells MW-134 and MW-135 at 6 and 38 µg/L respectively. These concentrations represent a slight decrease for MW-134 but an increase in the concentration of benzene for MW-135. Benzene was not detected in the three downgradient wells (MW-43, MW-35 and MW-158).

Using the measured values for hydraulic conductivity and gradient, and conservative published values for effective porosity for the clays and silts indicated on the boring logs, a groundwater velocity has been calculated as follows:

$$Velocity = \frac{Hydraulic\ Conductivity \times Gradient}{Porosity_{(effective)}}$$

$$Velocity = \frac{(1 \times 10^{-5} \text{ cm/sec}) \times (0.01)}{0.12} \qquad \text{Seepage Velocity} \approx 1 \text{ ft/yr}$$

The initial investigation into AOC 21 was triggered by the observation of an oily sheen on soils in an excavation during a water line repair job. The soils that were observed to be impacted were removed and the source of the “oily sheen” has never been identified. It is apparent, however, that the contamination evident in the groundwater is at low concentrations and it has not reached the property boundary. Chevron proposes continued monitoring of the six wells associated with this plume for a minimum of six additional rounds of sampling to determine concentrations trends for benzene in the groundwater.

8.1.4.2 AOC 27 - Tank 777 Pipeway and SWMU 10 – TEL Burial in Tank Basin 771

The dissolved phase volatile plume identified in this area is defined by benzene exceedances in wells MW-146 and MW-131 and several hydropunch samples collected as part of previous investigations (Figure 8-6). This plume extends from the south central portion of Tank Basin 777 to the western end of Tank Basin 771. Locally, groundwater flow from the western end of Tank Basin 771 is towards Tank Basin 777. Groundwater flow from Tank Basin 777 is to the North. Downgradient migration monitoring is provided by MW-43, MW-173 and MW-148. Upgradient monitoring is provided by MW-145 and MW-152.

During the fourth quarter of 2002, MW-131 was sampled twice; once in October and again in December. The only VOC exceedance was for benzene, and it was identified in both rounds of sampling. Benzene was detected at 180 µg/L in October and at 490 µg/L in December. MW-146 was only sampled once during the fourth quarter of 2002, and benzene was detected at 100 µg/L. Downgradient delineation of the plume is provided by HP0037, HP0042 and HP0043. The plume is delineated to the east by H0356, HP0040 and HP0041. Benzene was not detected in these hydropunches. The plume is

delineated to the west by A21TP1 and to the south (upgradient) by MW-145 and MW152. Ongoing downgradient monitoring is supplied by MW-43 and MW-148. VOCs were not detected in the downgradient wells MW-43 and MW-148, nor were they detected in the upgradient wells MW-145 and MW-152.

Based on the results of the first round of sampling, it was determined that an additional well was required to monitor downgradient of the plume. Therefore, MW-173 was installed approximately halfway between the downgradient wells MW-43 and MW-148. In addition, a second round of samples was collected to confirm the results of the fourth quarter 2002 sampling. This round of sampling was conducted during the first five months of 2003, and all seven wells were sampled. MW-131 was sampled twice.

The analytical results from the second round of sampling indicate the continued exceedances of benzene in MW-146 and MW-131. Benzene was detected in MW-146 at 48 µg/L, a decrease from the first round. However, in MW-131, benzene was detected at 870 µg/L in January, 2003 and 1,100 µg/L in April, 2003. While benzene was the only VOC exceedance detected in MW-146, cyclohexane was detected at 150 µg/L in both samples collected from MW-131.

VOCs were not detected in any of the three downgradient wells or in the two upgradient wells.

Some variation in the gradient is apparent across the area of study. The gradient between MW-146 and MW-173 is 0.0007 ft/ft. The average gradient between MW-145 and MW-173 is calculated at 0.0072 ft/ft. The gradient between MW-145 and MW-146 is 0.024 ft/ft. Given the wide range of gradients in this area, the approximate average value of 0.0072 ft/ft was selected to represent the average across the entire area associated with this benzene plume (Table 8-8).

Table 8-8. AOC 27 Groundwater Gradients

Well	Well	Distance (feet)	Elevation Change (feet)	Gradient (ft/ft)
MW-146	MW-173	500	0.37	0.0007
MW-145	MW-173	690	4.99	0.0072
MW-145	MW-146	190	4.62	0.024

The boring logs for this area describe the fill as sandy with a significant amount of silt and clay present. This would indicate the selected hydraulic conductivity is consistent with the fill material.

Using measured values for hydraulic conductivity and gradient and conservative published values for effective porosity for the clays, silts and sands indicated on the boring logs, a groundwater velocity has been calculated as follows:

$$\text{Velocity} = \frac{\text{Hydraulic Conductivity} \times \text{Gradient}}{\text{Porosity}_{(\text{effective})}}$$

$$\text{Velocity} = \frac{(1 \times 10^{-4} \text{ cm/sec}) \times (0.0072)}{0.15}$$

$$\text{Seepage Velocity} \approx 3 \text{ ft/yr}$$

The groundwater contamination in this area was identified during investigation of a TEL burial and remedial work associated with a pipeline release in Tank Basin 777. The presence of the TEL burial was confirmed during the 1st-Phase RFI for soils and remedial options for the TEL burials will be assessed during the CMS. The soils impacted by the pipeline release have been removed and the line repaired. Therefore, it is believed the source of the dissolved phase plume has been removed.

Chevron proposes continued monitoring of the seven wells (MW-145, MW-152, MW-146, MW-131, MW-043, MW-173, MW-148) associated with this plume for a minimum of six additional rounds of sampling. Groundwater samples collected from these wells will be analyzed for VOCs and lead. These data will be evaluated to determine if the TEL burial or other sources are providing additional contamination to the groundwater, or if the plume is degrading through natural attenuation.

8.1.4.3 SWMU 42 – Crude Slab

The dissolved phase volatile plume identified in this area is defined by benzene exceedances in wells MW-73, MW-157, RW-61, MW-141 and MW-51, and several hydropunch samples collected as part of previous or concurrent investigations (Figure 8-6). This plume extends from the Crude Slab east to MW-141 and through Tank Basins 750, 751, 752 and 753. Benzene concentrations of up to 2,000 µg/L (RW-61) have been identified in this plume. This plume encompasses three LNAPL areas (EY1, EY3 and SWMU 42). Further description of the LNAPL investigation is included in Section 7 of this report. Historically, Tanks 750, 751 and 752 were in gasoline service.

Groundwater flow in this area appears to be radial from MW-157. The plume is delineated by MW-152, MW-174 and MW-10 to the north; MW-142 to the east; MW-143 and MW-153 to the south; and MW-14 and MW-145 to the west. Monitoring wells within the plume include MW-73, RW-61, MW-51, MW-157 and MW-141.

During the first round of sampling (fourth quarter of 2002), benzene was found to exceed the delineation criterion in RW-61 and MW-141. MW-157 could not be sampled due to basin access problems. MW-73 and MW-51 also were not sampled due to the presence of LNAPL.

Based on the results of the first round of groundwater sampling, it was determined that one additional well (MW-174) was necessary to monitor the northern edge of the plume. A well of intermediate depth was also deemed necessary (MW-178) to determine if the first water bearing zone beneath the fill/native interface had been impacted.

The second round of sampling conducted during the first half of 2003 confirmed the presence of benzene in MW-141 and RW-61. MW-157 was also sampled in the second round and benzene was the only exceedance of the respective criterion at an estimated concentration of 4 µg/L. The wells downgradient of this plume continued to be free of VOCs and SVOCs (MW-152, MW-174, MW-10, MW-142, MW-143, MW-153, MW-14 and MW-145).

Groundwater samples from the intermediate depth well, MW-178, did not indicate the presence of VOCs, SVOCs or TICs. The groundwater elevation in MW-178 (+9.8 msl) does indicate that it is hydraulically separate from its shallow nested pair MW-141 (+14.09 msl).

The gradient in the area of this plume ranges from 0.01 to 0.035 ft/ft and averages approximately 0.02 ft/ft.

The boring logs for this area describe the fill as a mixture of clay sand and silt. For the purposes of the RFI, a hydraulic conductivity consistent with sandy silts will be used.

Using measured values for hydraulic conductivity and gradient and conservative published values for effective porosity for the clays, silts and sands indicated on the boring logs, a groundwater velocity has been calculated as follows:

$$Velocity = \frac{Hydraulic\ Conductivity \times Gradient}{Porosity_{(effective)}}$$

$$Velocity = \frac{(1 \times 10^{-4} \text{ cm/sec}) \times (0.0072)}{0.15} \qquad \text{Seepage Velocity} \approx 14 \text{ ft/yr}$$

The extent of this plume has primarily been derived from the results of the LNAPL investigation. The data generated as part of the LNAPL investigation indicates that some biodegradation of the plumes in this area is occurring. Therefore, Chevron feels it is appropriate to monitor the groundwater for an additional six additional rounds of sampling to determine if the degradation of the dissolved plume is occurring as well. Chevron proposes to monitor MW-152, MW-174, MW-10, MW-142, MW-143, MW-153, RW-61, MW-157 and MW-141. Groundwater samples will be analyzed for VOCs only.

8.1.4.4 AOC-31 - Tank Basin 772 Pump Pad

The dissolved phase plume in this area is defined by the exceedances of benzene and other VOCs in MW-90 and hydropunches H0455, H0544, and H0346 (Figure 8-6). Locally, groundwater flow is primarily to the north. The plume has been delineated to the east by groundwater samples from locations identified as H0454 and H0464, both of which were non-detect for benzene. The plume has been delineated to the west by groundwater samples from locations identified as H0345 and H0456. These samples were all collected in the fourth quarter of 1999 and the first half of 2000 as part of the

OWSS Investigation. Upgradient delineation for this area is provided by MW-10 and downgradient migration monitoring is provided by MW-9.

Initially, MW-90 was installed to determine if LNAPL was present. LNAPL has never been detected in this area; however, benzene groundwater concentrations exceeding delineation criteria have been identified. MW-90 was not sampled during the fourth quarter of 2002 due to an oversight. The results of the sampling conducted in the first five months of 2003 indicated the presence of benzene at 3,600 µg/L. This exceedance of the delineation criterion was accompanied by other VOC exceedances including cyclohexane (420 µg/L), ethylbenzene (830 µg/L), methylcyclohexane (250 µg/L) and xylene (2,300 µg/L). SVOCs were not detected.

MW-9 and MW-10 were both sampled in the fourth quarter of 2002 and during the second round in 2003. No VOC or SVOC exceedances were detected in either sampling round.

The gradient in this area is very low and has been calculated as less than 0.0001 ft/ft based on groundwater elevation measurements taken from MW-10 and MW-9.

Based on the boring logs, fill in this area is as much as 16 feet thick and is composed of a variety of materials from silty sand to silty clays.

Using measured values for hydraulic conductivity and gradient and conservative published values for effective porosity for the clays, silts and sands indicated on the boring logs, a groundwater velocity has been calculated as follows:

$$Velocity = \frac{Hydraulic\ Conductivity \times Gradient}{Porosity_{(effective)}}$$
$$Velocity = \frac{(1 \times 10^{-4} \text{ cm/sec}) \times (0.0001)}{0.15} \qquad \text{Seepage Velocity} < 1 \text{ ft/yr}$$

Based on these groundwater velocity calculations, and without accounting for retardation and degradation, the dissolved benzene now evident in MW-90 could take more than 200 years to reach the northern property boundary.

The source of the benzene in this area has been identified as historic leaks from the pump pad located in the Basin. The pump pad and petroleum contaminated soil have been removed. These activities are documented in the *SWMU Assessment Report* submitted January 26, 2000. The plume appears to be small and limited to the eastern portion of Tank Basin 772.

Chevron proposes continued monitoring of the three wells (MW-9, MW-10 and MW-90) associated with this plume for a minimum of six additional rounds of sampling. This will help to determine if there is an ongoing source of groundwater contamination or if the

plume is degrading through natural attenuation. The groundwater will be analyzed for VOCs only.

8.1.4.5 SWMU 8 – TEL Burial

The dissolved plume in this area is defined by the detection of benzene in HP103 at 69 µg/L and MW-132 at 700 µg/L. This plume appears to be limited in extent and directly associated with leaded sludges that records indicate were buried at this location (Figure 8-6). The available groundwater elevation data indicates flow to the east towards SB-15. The plume is delineated to the west by H0460 and to the south by H0407 and SB-14. Upgradient to MW-132, groundwater samples from HP117 (1st-Phase RFI hydropunch) indicated low levels of benzene at 6 µg/L. Downgradient, SB-15 has not shown any evidence of benzene throughout the RFI investigation.

MW-132 was initially installed to determine if groundwater had been impacted by hydrocarbon contamination identified in soils. The results of the first round of samples indicated the presence of benzene at 700 µg/L. Also detected in the groundwater were chlorobenzene (580 µg/L), cyclohexane (150 µg/L) and 1,4-dichlorobenzene (250 µg/L). Some compounds also were detected in the SVOC scan; methylcyclohexane (100 µg/L), dimethylphenol (169 µg/L), naphthalene (310 µg/L) and 2-methylnaphthalene (180 µg/L). Phthalates were also detected, but these are common contaminants associated with groundwater sample collection and analysis.

Based on the results of the first round of sampling, it was determined that additional monitoring should be conducted. Due to access problems, it was deemed impractical to install an additional well north of MW-132. However, a second round of samples was collected from the monitoring wells.

The data from the second round of samples confirmed the presence of benzene (900 µg/L), chlorobenzene (210 µg/L), cyclohexane (250 µg/L) and methylcyclohexane (310 µg/L). Xylenes at 1,200 µg/L were also detected in the groundwater during the second round of sampling. Dimethylphenol was the only SVOC detected in excess of the delineation criterion.

The gradient calculated from groundwater elevations measured in MW-132 and SB-15 is 0.02 ft/ft. The fill material is up to 16 feet thick and is described primarily as silty sand.

Using measured values for hydraulic conductivity and gradient and conservative published values for effective porosity for the clays, silts and sands indicated on the boring logs, a groundwater velocity has been calculated as follows:

$$Velocity = \frac{Hydraulic\ Conductivity \times Gradient}{Porosity_{(effective)}}$$

$$Velocity = \frac{(1 \times 10^{-4} \text{ cm/sec}) \times (0.02)}{0.15}$$

$$Seepage\ Velocity \approx 15 \text{ ft/yr}$$

The groundwater impacts in this area were identified during investigation of a TEL burial (SWMU 8). The soil contamination associated with the burial is limited in extent, and it appears the groundwater contamination may also be limited. The apparent remedial action for the TEL burial will be determined in the CMS. In the interim, Chevron proposes continued monitoring of groundwater for six rounds to determine concentration trends. Groundwater samples from MW-132 and SB-15 will be analyzed for VOCs, SVOCs and metals.

8.1.4.6 AOC-6B and AOC 29 - Oily Fill Area

This area is located in the southeastern portion of the East Yard (Figure 8-6). The dissolved phase contaminants are defined by some scattered exceedances of benzene in hydropunch samples collected as part of the OWSS Investigation. Specifically, benzene was detected in groundwater samples: H0351 (150 µg/L), H0354 (690 µg/L), H0355 (2 µg/L), H0379 (10 µg/L) and H0388 (39 µg/L). Other benzene detections in this area include MW-155 and MW-156 at 4 and 2 µg/L, respectively. The intermittent presence of LNAPL on the northern edge of this plume has been noted (LNAPL Area EY4A). There are also numerous groundwater samples from this area in which benzene was not detected.

Locally, groundwater flow is to the east. The discontinuous plume has been delineated to the north by H0466, to the east (upgradient) by H0349 and MW-8, to the south by MW-7, and to the east by downgradient wells MW-155 and MW-156. During the RFI, MW-151 was installed to confirm the presence of benzene initially detected in the hydropunch samples. MW-151 was located near the center of the benzene detections based on the available evidence. The boring log indicated the presence of sandy material and slag. These were accompanied by descriptions of petroleum odors, tar and a “sheen”. However, benzene was not detected in MW-151 in the two samples collected from this well, nor was any other VOC or SVOC.

The average gradient for this area is measured between MW-8 and MW-156 and is approximately 0.01 ft/ft. The fill material in this area is approximately 8 to 10 feet thick and is described in many of the boring logs as sandy with various amounts of clay, silt, gravel, flyash and slag.

Using measured values for hydraulic conductivity and gradient and conservative published values for effective porosity for the clays, silts and sands indicated on the boring logs, a groundwater velocity has been calculated as follows:

$$Velocity = \frac{Hydraulic\ Conductivity \times Gradient}{Porosity_{(effective)}}$$

$$Velocity = \frac{(1 \times 10^{-4} \text{ cm/sec}) \times (0.01)}{0.15}$$

$$Seepage\ Velocity \approx 7 \text{ ft/yr}$$

The scattered detections of benzene in this area may be associated with the flyash and slag in the fill material or the residual LNAPL in EY4A. The detections are discontinuous and therefore limited in extent. At present, only the downgradient wells MW-155 and MW-156 display evidence of contamination and that at very low levels. The benzene that has been detected in MW-155 and MW-156 has declined through the two sampling events that have occurred. Neither benzene nor other volatile and semi-volatile compounds have been detected in MW-7, MW-8 or MW-151 in the two sampling rounds conducted to date. Chevron proposes continued monitoring of MW-151, MW-7, MW-8, MW-155 and MW-156 for 6 additional periods to determine the mobility of benzene in this area and contaminant concentration trends. In an effort to determine if the LNAPL in EY4A is the source of the groundwater contamination, RW-94 will be added to the sampling events. Groundwater will be analyzed for VOCs only.

8.1.4.7 AOC 26 and AOC 14 - East Yard Bunker Slab

The dissolved phase volatile plume identified in this area is defined by benzene exceedances in MW-149 and several hydropunch samples collected as part of previous investigations (Figure 8-6). The plume is consistent with the LNAPL area identified as EY4 in Section 7 of this report. Locally, groundwater flow is to the east. Downgradient migration monitoring is provided by MW-144, MW-175 and MW-171. Upgradient monitoring is provided by MW-142.

During the fourth quarter of 2002, MW-144 and MW-149 were sampled. The only VOC exceedance was benzene in the MW-149 sample (9 µg/L). Downgradient delineation of the plume is provided by H0842, H0841 and MW-144. The plume is delineated to the north by SB-16 and to the south by H0357 and H0466. Upgradient, to the east, the plume is delineated by H0358, H0361 and MW-142. Some earlier hydropunch results such as the 1,100 µg/L of benzene detected in H0218 have not been substantiated by the analysis of groundwater samples collected from wells. MW-144 was placed near the location of H0218 and has been non-detect for benzene for two rounds of samples.

Based on the results of the first round of sampling, it was determined that two additional wells were required to monitor downgradient migration of the plume. Accordingly, MW-171 and MW-175 were installed. In addition, a second round of samples was collected to confirm the results of the fourth quarter 2002 sampling. This round of sampling was conducted during the first five months of 2003 and the five wells associated with this plume were sampled.

The analytical results from the second round of sampling indicate the continued presence of benzene in MW-149 (8 µg/L). Benzene was the only VOC exceedance detected.

VOCs were not detected in any of the three downgradient wells (MW-144, MW-175 and MW-171) or in the one upgradient well (MW-142).

The gradient in this area approximates 0.01 ft/ft.

Using measured values for hydraulic conductivity and gradient and conservative published values for effective porosity for the clays, silts and sands indicated on the boring logs, a groundwater velocity has been calculated as follows:

$$Velocity = \frac{Hydraulic\ Conductivity \times Gradient}{Porosity_{(effective)}}$$

$$Velocity = \frac{(1 \times 10^{-4} \text{ cm/sec}) \times (0.01)}{0.15}$$

$$Seepage\ Velocity \approx 7 \text{ ft/yr}$$

The groundwater contamination and LNAPL were identified in this area during investigation of the Bunker Slab (AOC 26). Based on the data collected to date, the dissolved phase plume appears to be emanating from the LNAPL. Therefore, Chevron proposes continued monitoring of the six wells (MW-142, MW-144, MW-149, MW-175, MW-171 and RW-83) associated with this plume. Upgradient monitoring is provided by MW-142, and downgradient migration monitoring is provided by MW-144, MW-171 and MW-175. Wells within the plume include RW-83 and MW-149. The monitoring is proposed for a minimum of six additional rounds of quarterly sampling. This will help to determine if the LNAPL is a continuing source of contamination to the groundwater or if the plume is degrading through natural attenuation.

8.1.4.8 MW-6

Benzene has been detected in MW-6 during both rounds of sampling conducted as part of the RFI activities. Based on the groundwater flow regime in the shallow water table derived from the June 5, 2003 groundwater elevation data, MW-6 is in an upgradient location. Numerous hydropunches have been conducted in the general vicinity of this well (Figure 8-6) and none of these have indicated the presence of benzene on Refinery property. The conclusion drawn from the data indicates that the source of the benzene is either immediately adjacent to MW-6 (which is not likely since it is located adjacent to a road that separates it from the Refinery), or it is from the upgradient neighboring property.

8.1.4.9 Historical Hydropunch Detections

Benzene has been detected during previous investigations of the groundwater in the East Yard. These detections have been in samples collected from hydropunches and/or temporary well points. These detections are summarized on Figure 8-6. The majority of these detections are incorporated in the dissolved phase plumes previously discussed. However, five benzene exceedances were not included. The groundwater samples were collected as part of the Phase II OWSS Investigation conducted in 1999. The samples and benzene detections are as follows:

- H0406 – 500 µg/L;
- H0448 – 150 µg/L;

- H0359 – 49 µg/L;
- H0347 – 3 µg/L; and
- H0376 – 8 µg/L.

H0406

This sample was collected immediately west of the EYB. The extent of the benzene detected in H0406 appears to be limited. Delineation is provided by H0404 and H0405 to the west and north, SB-16 to the south, and MW-150 and SB-17 to the east. If there is an ongoing source of benzene in this area, continued downgradient monitoring is provided by MW-150 and SB-17.

H0448 and H0359

These samples were collected in Tank Basins 760 and 765, respectively. These detections may in fact be part of the dissolved phase plume described for AOC 26 – East Yard Bunker Slab. The benzene detected in H0359 is delineated by H0361, H0360, H0385 and H0358 to the north, west, south and east, respectively. The detection of benzene in the H0448 sample is partially delineated by MW-10 and SB-16 to the north and H0361 to the south. To the east, higher concentrations of benzene are evident in the AOC 26 dissolved phase plume. Continued monitoring of the groundwater conditions in this area will be provided by the monitoring network described for the AOC 26 plume.

H0347 and H0376

These samples were collected in the southeastern portion of the East Yard in and near Tank Basin 757. These are low-level detections that together are delineated by H0374 and H0375 to the west and south, and H0377 to the east. To the north, delineation is provided by H0901. Ongoing monitoring of the groundwater conditions in this area is provided by MW-8 and downgradient well MW-7.

8.2 North Field/Main Yard

This section discusses the surficial geology of the North Field/Main Yard, the results of the groundwater investigation and the distribution of contaminants in the North Field/Main Yard groundwater. The assessment of North Field/Main Yard groundwater conditions is based on data collected from 54 wells that were installed as part of the RFI or previous investigations. These wells are shown on Figure 8-10. They include the following:

- Pre RFI wells – 20 wells;
- Closure wells – six shallow wells;
- LNAPL Investigation well – one shallow well; and
- RFI wells – 24 shallow wells and three deep wells.

The deep wells (P-9, MW-180 and MW-115) are screened in the first water bearing zone beneath the fill/native interface. Together, the shallow and deep wells provide the monitoring network for the North Field/Main Yard. One round of water level measurements and two rounds of groundwater samples have been collected from most wells.

8.2.1 Geology

The North Field/Main Yard is composed of varying amounts of fill ranging in thickness from three feet to as much as 15 feet, overlying a glacial till and a discontinuous clay/peat layer. Where the clay and peat are present, they overlie the till. The clay, also described as Clay Horizon A, can be as much as 30 feet thick in close proximity to Woodbridge Creek. The glacial till appears to be continuous across the North Field/Main Yard and is characterized by varying amounts of reddish brown clays, silts, sands and gravels. The till is up to 40 feet in thickness and in some areas extends down to the Farrington Sand (Sand Horizon B). In most of the North Field/Main Yard, Clay Horizon B (Woodbridge Clay) lies between the till and the Farrington Sand.

One boring log (MW-180) indicates the presence of discontinuous deposits of light gray sands and clays at depths of 15 to 25 feet bgs within the till. These appear to be coastal marine deposits stratigraphically equivalent to Clay Horizon A. These sands and clays may represent the remnants of drainage features where the till has been removed through erosion and the sands and clays were deposited during a subsequent rise in sea level.

Five cross sections are included (Figures 8-11 through 8-15) to illustrate the relationships of the fill and shallow native materials. The locations of the cross sections are shown on Figure 8-10.

8.2.2 Hydrogeology

The shallow groundwater in the North Field/Main Yard is found unconfined in the fill material, perched on the native clay, peat and till. On June 19, 2003 groundwater elevations were measured in 53 of the 54 wells. The results of this elevation data has been presented on Figure 8-10. As shown, groundwater generally flows in a northeasterly direction from highs of 11 to 12 feet above MSL in the southwestern portion of the Yard to lows of two to four feet above MSL along Woodbridge Creek.

Gradients measured across the North Field/Main Yard range from 0.15 to less than 0.001 ft/ft and average 0.005 ft/ft. Gradients representative of the overall conditions in the North Field/Main Yard are provided by groundwater elevation measurements between MW-138 in the southwestern portion of the North Field/Main Yard and MW-136 and NF-14 to the northeast (Table 8-9).

Table 8-9. North Field/Main Yard Gradients

Well	Well	Distance (feet)	Elevation Change (feet)	Gradient
MW-138	MW-136	1,330	7.84	0.006
MW-138	NF-14	1,840	8.52	0.005

The groundwater data from a group of wells in the interior of the North Field/Main Yard (MW-123, MW-72, RW-21, MW-116 and MW-117) indicate that a low area exists in the water table paralleling Woodbridge Creek. This is in part caused by the sheet pile installed on the southern edge of the NFB and the western edge of the Surge Pond. Another contributing factor is the tendency of the native clay and peat to be compacted by the loading of fills and structures. In close proximity to Woodbridge Creek, the fill is thin and no structures are present, so the peat and clay are less compacted and structurally higher (see cross section presented in Figure 8-11).

The effect of the sheet pile on groundwater flow is demonstrated by the gradient that can be measured from MW-70 and MW-57 towards the depression in the water table evident in Tank Basins 302 and 330. The gradient indicates a localized southwesterly flow direction. The effect of the differential compaction of the native clay and peat by loading can be seen in the vicinity of Tanks 301 and 327. The gradient between MW-31, MW-32, MW-124 and MW-117 also indicate a localized southwesterly flow.

For the purposes of the RFI, hydraulic conductivities measured by aquifer tests conducted by Woodward Clyde Associates (1982) were used. As part of the Woodward Clyde hydrogeologic study at the Refinery, several wells screened across the fill, till, Clay Horizon A and Sand Horizon A were tested to determine their hydraulic conductivity. The results of the slug tests indicated conductivities ranging from 1×10^{-2} cm/sec in Sand Horizon A to 4×10^{-6} cm/sec in Clay Horizon A. Since the vast majority of shallow fill materials found in the North Field/Main Yard consist of a mixture of silts, sands and clay similar in nature to the till and Clay Horizon A, with a hydraulic conductivity ranging between 4×10^{-6} cm/sec and 1×10^{-3} cm/sec, 1×10^{-4} cm/sec has been selected as a conservative estimate of overall site conditions.

Published values (Fetter, 1988) have been used to estimate the effective porosity of unconsolidated materials similar to the North Field/Main Yard fill. The estimates of conductivity and effective porosity, and the measured gradients have been used to determine estimated seepage velocities for groundwater in the vicinity of the dissolved contaminant plumes found in the North Field/Main Yard. The published values used are presented in Table 8-10 below.

Table 8-10. North Field/Main Yard Soil Parameters

Fill Material	Estimated Hydraulic Conductivity	Estimated Effective Porosity
Sand	1×10^{-2} cm/sec	25%
Silty Sand, Fine Sand	1×10^{-3} cm/sec	20%
Silt, Sandy Silt, Clayey Sand	1×10^{-4} cm/sec	15%
Silty Clay	1×10^{-5} cm/sec	12%
Clay	1×10^{-6} cm/sec	10%

In general, seepage velocities of groundwater have been found to be low. This is primarily due to low gradients and the limited permeabilities of the fill/native material. It must be noted that the seepage velocities presented are not rates of transport for contaminants, as they don't account for retardation and degradation. The need to calculate these rates will be determined subsequent to the collection of additional analytical data.

8.2.3 Groundwater Chemistry

8.2.3.1 Contaminant Distribution – First Round

During the fourth quarter of 2002, a round of groundwater samples was collected from the existing North Field/Main Yard monitoring well system. A total of 49 wells were sampled during this period. Of these, groundwater samples from 42 wells were analyzed for RFI parameters including VOCs, SVOCs and metals. Also included were tests for alkalinity, hardness, chlorides, sulfates, nitrites, nitrates and TDS. Of the remaining seven wells, samples from one (RW-42) was analyzed for VOC s and SVOCs only, and samples from seven wells (NF-10 through NF-16) were analyzed for closure parameters (a limited list of volatile and semi-volatile compounds). A library search for TICs was conducted for 48 of the 49 samples. The search contained 10 volatile TICs and 20 semi-volatile TICs for each sample.

VOC Results

VOCs were detected above the groundwater delineation criteria (NJDEP Class IIA GWQC) in 13 of the 49 wells sampled (Figure 8-16). Benzene accounted for 12 of the 13 detections. Benzene was the only VOC exceedance in nine of these 12 samples. Three wells (MW-117, MW-118 and NF-10) contained benzene and other VOC exceedances (Table 8-11).

Table 8-11. North Field/Main Yard First Round VOC Results

Compounds (results in µg/l)	MW-117	MW-118	NF-10
Benzene (Criterion = 1 µg/L)	1,900	15	650
Methyl t-butyl ether (Criterion = 70 µg/L)	240	NE	NS
Cyclohexane (Criterion = 100 µg/L)	NE	180	NS
Xylene (Criterion = 1,000 µg/L)	NE	NE	1,200

NS Not sampled

NE Does not exceed criterion

MW-117 and MW-118 were both installed in close proximity to TEL burial sites. NF-10 is a well monitored for the Closure Project that has shown evidence of BTEX contamination for an extended period of time. These results will be examined further in the following discussions specific to these areas.

One well (MW-115) contained two VOC exceedances (bromodichloromethane and chloroform) but did not contain benzene. Bromodichloromethane and chloroform are disinfection products found in treated drinking water. It was thought at the time that these were artifacts from the installation of the well that had not been completely removed during well development.

Methane was also detected in samples from four wells ranging in concentration from 650 to 7,200 µg/l. All four of the wells in which methane was detected are shallow and screened at or near the highly organic peat layer found at the base of the fill. The presence of methane is believed to be attributable to the breakdown of this native organic material and is not indicative of a release from a Refinery-related process.

SVOC Results

SVOCs were detected in excess of the groundwater delineation criteria in seven of the 49 wells sampled (Figure 8-18). Of the seven exceedances, five were for petroleum-related compounds. The phthalates detected in MW-13 and P-4 are common contaminants associated with sample handling procedures and are not evaluated further (Table 8-12).

Petroleum related SVOC exceedances were detected in MW-117, MW-65, MW-21, RW-42 and MW-121. The groundwater sample from MW-117 contained a variety of phenolic compounds which included 2,4-dimethylphenol (40,000 µg/l), phenol (13,000 µg/l), 2-methylphenol (64,000 µg/l) and 4-methylphenol (69,000 µg/l). MW-117 was installed in close proximity to a confirmed leaded burial site.

Three of the other four wells (MW-65, MW-21 and MW-121) contained a mix of PAHs including chrysene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene and benzo(k)fluoranthene. These compounds have very low

Table 8-12. North Field/Main Yard Summary of SVOC Exceedances

Compound (Results in µg/L)	MW-021		MW-065		MW-117		MW-121		MW-123		MW-180		NF-12		RW-42	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
2,4-Dimethylphenol (Criterion = 100 µg/L)	NE	NE	NE	NS	40,000	55,000	NE	NE	NE	620	NS	280	NS	NS	NE	NS
2-Methylphenol (Criterion = 100 µg/L)	NE	NE	NE	NS	64,000	77,000	NE	NE	NE	NE	NS	110	NS	NS	NE	NS
4-Methylphenol (Criterion = 100 µg/L)	NE	NE	NE	NS	69,000	87,000	NE	NE	NE	NE	NS	NE	NS	NS	NE	NS
Phenol (Criterion = 4,000 µg/L)	NE	NE	NE	NS	13,000	18,000	NE	NE	NE	NE	NS	NE	NS	NS	NE	NS
2-Methylnaphthalene (Criterion = 100 µg/L)	NE	NE	NE	NS	NE	NE	NE	NE	NE	NE	NS	NE	NS	NS	NE	NS
Chrysene (Criterion = 5 µg/L)	NE	NE	36	NS	NE	NE	8J	NE	NE	NE	NS	NE	NE	NE	NE	NS
Benzo(a)anthracene (Criterion = 0.2 µg/L)	2J	NE	24	NS	NE	NE	NE	3J	NE	NE	NS	NE	NE	1J	NE	NS
Benzo(a)pyrene (Criterion = 0.2 µg/L)	2J	NE	39	NS	NE	NE	NE	3J	NE	NE	NS	NE	NE	2J	NE	NS
Benzo(b)fluoranthene (Criterion = 10 µg/L)	NE	NE	19	NS	NE	NE	NE	NE	NE	NE	NS	NE	NE	NE	NE	NS
Benzo(k)fluoranthene (Criterion = 1 µg/L)	NE	NE	4	NS	NE	NE	NE	NE	NE	NE	NS	NE	NE	NE	NE	NS
Carbazole (Criterion = 5 µg/L)	NE	NE	NE	NS	NE	NE	NE	NE	NE	NE	NS	NE	NS	NS	NE	NS
Dibenz(a,h)anthracene (Criterion = 0.5 µg/L)	NE	NE	9	NS	NE	NE	NE	NE	NE	NE	NS	NE	NE	NE	NE	NS
Indeno(1,2,3-cd)pyrene (Criterion = 10 µg/L)	NE	NE	11	NS	NE	NE	NE	NE	NE	NE	NS	NE	NS	NS	NE	NS
Caprolactam (Criterion = 100 µg/L)	NE	NE	NE	NS	NE	NE	NE	NE	NE	NE	NS	NE	NS	NS	270	NS

Exceeds one or more criteria

NS Not sampled

NE Does not exceed criterion

solubilities. The presence of these compounds in the groundwater samples is attributable to their adsorption to fine particles suspended in the sample. TDS was measured in two of the three samples at levels that exceed the NJDEP Class IIA GWQC. TDS in MW-21 was measured at 1,090,000 µg/l and in MW-121 at 4,540,000 µg/l. This indicates these compounds are neither dissolved nor mobile in groundwater.

Finally, the groundwater sample from RW-42 contained 270 µg/l of caprolactam, an additive used to make nylon rope; however, the Refinery has never been involved in this process. Nylon rope is used for sampling purposes at the Refinery. A segment of sampling rope was analyzed using an ASTM DI Leach test. The results indicated caprolactam in the leachate. Accordingly, Chevron believes the caprolactam in RW-42 to be a product of field sampling procedures.

Metals Results

Metals were detected in the majority of the wells in the North Field/Main Yard in excess of the groundwater delineation criteria (Table 8-13). These included naturally-occurring iron, manganese and, to a lesser extent, aluminum. The presence of these metals in the groundwater is attributed to the clays that are included in the fill material and the native soil. Chevron does not consider these analytes to be COCs and they are not evaluated further.

Groundwater from 47 wells was analyzed to determine the presence of metals. Metals were detected in 15 of these samples (Figure 8-19). The analyte most often encountered was arsenic. Arsenic was encountered in 11 wells ranging in concentration from 8 to 23.8 µg/l. Thallium was detected in five of the wells ranging in concentration from 12.5 to 26.7 µg/l. Other exceedances included nickel in two wells and cobalt, cadmium and lead in one well each.

Tentatively Identified Compounds

Of the 49 wells sampled during the fourth quarter of 2002, groundwater from 42 was analyzed for TICs (Table 8-14). The initial review of the TIC data indicated the presence of 4-hydroxy-4-methyl-2-pentanone and 2-methoxy-2-methyl-butane in numerous samples. Upon review with the laboratory, it was determined that these compounds are condensation products created in the laboratory during sample extraction. Therefore, these compounds are not included in the following evaluation.

TICs were found in 16 of the 42 samples. Of these, nine were associated with wells where benzene had been detected in excess of the groundwater delineation criterion. Since benzene will be addressed in these locations and serve as a surrogate for the TICs, no further TIC-specific evaluation was conducted. Of the remaining seven, none of the identifiable compounds (those with CAS numbers) were found to have evidence of carcinogenicity. Further, none of the TICs exceeded the individual interim generic organic criterion of 100 µg/L, nor did the combined total TIC concentrations exceed the 500 µg/L total organic criterion for non-carcinogens.

Table 8-13. North Field/Main Yard Metals Data

Well	Arsenic (Criterion = 8 µg/L)		Lead (Criterion = 10 µg/L)		Cadmium (Criterion = 4 µg/L)		Cobalt (Criterion = 100 µg/L)		Nickel (Criterion = 100 µg/L)		Thallium (Criterion = 10 µg/L)	
	Round 1	Round 2	Round 1	Round 2	Round 1	Round 2	Round 1	Round 2	Round 1	Round 2	Round 1	Round 2
P-2	NE	NE	NE	NE	NE	6.6J	NE	NE	NE	NE	NE	NE
P-4	21.4	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	26
P-5	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	17J
P-6	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
MW-002	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
MW-003	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	26.7	NE
MW-005	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
MW-012	NE	NE	NE	NE	NE	24	NE	NE	NE	NE	NE	13J
MW-013	16.1	NE	NE	NE	NE	NE	139	NE	315	NE	NE	NE
MW-020	9.6J	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
MW-021	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
MW-024	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
MW-030	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
MW-031	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
MW-032	NE	13	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
MW-034	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
MW-039	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
RW-42	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
MW-057	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
MW-065	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
MW-112	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
MW-114	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
MW-115	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
MW-117	9.2	18	NE	73	NE	NE	NE	NE	NE	NE	NE	NE
MW-118	9.8J	14	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
MW-120	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	13.8	NE
MW-121	23.8	NE	NE	NE	4.1J	NE	NE	NE	NE	NE	18.4	NE
MW-122	20.1	11	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
MW-123	NE	NE	NE	30.2	NE	NE	NE	NE	NE	NE	12.5J	NE
MW-124	8.7J	NE	NE	NE	NE	NE	NE	NE	NE	NE	69.4	NE
MW-125	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE

Table 8-13. North Field/Main Yard Metals Data

Well	Arsenic (Criterion = 8 µg/L)		Lead (Criterion = 10 µg/L)		Cadmium (Criterion = 4 µg/L)		Cobalt (Criterion = 100 µg/L)		Nickel (Criterion = 100 µg/L)		Thallium (Criterion = 10 µg/L)	
	Round 1	Round 2	Round 1	Round 2	Round 1	Round 2	Round 1	Round 2	Round 1	Round 2	Round 1	Round 2
MW-126	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
MW-127	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
MW-128	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
MW-133	NE	NS	NE	NS	NE	NS	NE	NS	NE	NS	NE	NS
MW-136	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
MW-137	12.6	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
MW-138	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
MW-139	10	NE	14.6J	NE	NE	NE	NE	NE	NE	NE	NE	11J
MW-140	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
MW-154	NE	8.4J	NE	NE	NE	NE	NE	NE	NE	NE	NE	54
MW-159	10.9	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
NF-10	NS	NE	NE	NE	NE	NE	NS	NS	NE	NE	NS	NS
NF-11	NS	NE	NE	NE	NE	NE	NS	NS	NE	NE	NS	NS
NF-12	NE	NE	NS	NE	NS	NE	NS	NS	NS	NE	NS	NS
NF-13	NE	NE	NE	NE	NE	NE	NS	NS	163J	NE	NS	NS
NF-14	NE	NE	NE	NE	NE	NE	NS	NS	NE	NE	NS	NS
NF-15	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
NF-16	NS	NE	NE	22.8	NE	NE	NS	NS	NE	NE	NS	NS
NF-16	NS	NS	NE	NS	NE	NS	NS	NS	NE	NS	NS	NS
MW-164	NS	NE	NS	NE	NS	NE	NS	NE	NS	NE	NS	NE
MW-165	NS	NE	NS	NE	NS	NE	NS	NS	NS	NE	NS	NE
MW-166	NS	NE	NS	NE	NS	NE	NS	NS	NS	NE	NS	NE
MW-033	NS	31.7	NS	15.4J	NS	NE	NS	NS	NS	NE	NS	NE
MW-179	NS	10.6	NS	NE	NS	NE	NS	NS	NS	NE	NS	NE
MW-180	NS	NE	NS	NE	NS	NE	NS	NS	NS	NE	NS	13.2J

NS Exceeds benzene criterion
 Not sampled
 NE Does not exceed criterion

Table 8-14. North Field/Main Yard Benzene and TIC Data (µg/L)

Well	Benzene Round 1	VOC TICs Round 1			SVOC TICs Round 1			Benzene Round 2	VOC TICs Round 2			SVOC TICs Round 2		
		No.	Single	Total	No.	Single	Total		No.	Single	Total	No.	Single	Total
P-2	NE	0	0	0	10	11	69	NE	0	0	0	2	150	156
P-4	NE	0	0	0	7	20	73	NE	0	0	0	3	6	16
P-5	NE	0	0	0	3	10	21	NE	0	0	0	0	0	0
P-6	NE	0	0	0	0	0	0	NE	0	0	0	3	39	58
MW-002	NE	0	0	0	0	0	0	NE	0	0	0	1	6	6
MW-003	NE	0	0	0	6	200	273	NE	0	0	0	7	110	163
MW-005	NE	0	0	0	6	14	48	NE	0	0	0	4	15	37
MW-012	NE	0	0	0	3	50	106	NE	0	0	0	1	12	12
MW-013	NE	0	0	0	3	10	26	NE	0	0	0	1	7	7
MW-020	NE	2	11	18	19	19	181	NE	1	14	14	12	16	83
MW-021	NE	0	0	0	20	55	431	NE	0	0	0	3	10	23
MW-024	NE	0	0	0	20	54	238	NE	0	0	0	0	0	0
MW-030	NE	0	0	0	0	0	0	NE	0	0	0	0	0	0
MW-031	NE	0	0	0	3	7	18	NE	0	0	0	1	16	16
MW-032	NE	2	10	15	19	17	173	NE	0	0	0	7	6	37
MW-034	NE	1	15	15	0	0	0	NE	1	6	6	19	30	321
MW-039	12	9	54	116	9	55	119	29	9	83	184	10	40	103
RW-42	2	4	11	33	1	10	10	NS	NS	NS	NS	NS	NS	NS
MW-057	NE	0	0	0	0	0	0	NS	NS	NS	NS	NS	NS	NS
MW-065	6	1	8	8	20	150	1,944	NS	NS	NS	NS	NS	NS	NS
MW-112	NE	0	0	0	2	6	11	NE	0	0	0	0	0	0
MW-114	NE	0	0	0	2	6	11	NE	0	0	0	0	0	0
MW-115	NE	0	0	0	0	0	0	NE	0	0	0	0	0	0
MW-117	1,900	8	1,000	2,250	20	8,700	44,250	1,100	9	320	764	20	13,000	65,210
MW-118	15	10	100	405	20	140	776	15	10	130	578	19	120	944
MW-120	NE	0	0	0	2	8	14	NE	0	0	0	2	10	18
MW-121	10	10	34	160	19	760	2,429	3J	8	20	100	19	54	778
MW-122	290	9	160	780	17	110	522	350	9	220	966	19	280	1,008
MW-123	260	9	350	1,562	25	300	2,715	290	10	810	3,180	20	370	3,276
MW-124	NE	1	24	24	18	110	251	NE	1	12	12	20	85	331
MW-125	800	9	88	406	20	130	727	19	3	8	22	4	7	22
MW-126	NE	0	0	0	20	130	721	NE	0	0	0	4	21	33
MW-127	NE	0	0	0	5	8	31	NE	0	0	0	3	11	20
MW-128	NE	10	32	189	20	26	201	NE	4	10	27	3	20	37
MW-133	2J	10	42	212	20	59	977	NS	NS	NS	NS	NS	NS	NS

Table 8-14. North Field/Main Yard Benzene and TIC Data (µg/L)

Well	Benzene Round 1	VOC TICs Round 1			SVOC TICs Round 1			Benzene Round 2	VOC TICs Round 2			SVOC TICs Round 2		
		No.	Single	Total	No.	Single	Total		No.	Single	Total	No.	Single	Total
MW-136	NE	0	0	0	0	0	0	NE	0	0	0	11	19	81
MW-137	NE	0	0	0	3	15	25	NE	3	7	19	14	8	83
MW-138	NE	0	0	0	6	5	28	NE	0	0	0	0	0	0
MW-139	NE	10	25	120	19	14	179	NE	10	24	130	20	13	139
MW-140	NE	0	0	0	1	6	6	NE	0	0	0	1	5	5
MW-154	NE	0	0	0	16	16	111	NE	0	0	0	12	100	279
MW-159	NE	10	15	78	7	8	52	NE	10	14	82	19	77	222
NF-10	650	NS	NS	NS	15	360	2,527	790	15	510	4,250	25	490	3,206
NF-10	NS	NS	NS	NS	NS	NS	NS	680	NS	NS	NS	NS	NS	NS
NF-11	190	NS	NS	NS	15	220	935	94	15	290	2,174	25	150	853
NF-11	NS	NS	NS	NS	NS	NS	NS	120	NS	NS	NS	NS	NS	NS
NF-12	NE	NS	NS	NS	2	8	12	NE	1	8	8	25	110	936
NF-13	NE	NS	NS	NS	8	40	109	NE	1	49	49	6	1,600	1,635
NF-13	NS	NS	NS	NS	NS	NS	NS	NE	NS	NS	NS	NS	NS	NS
NF-14	NE	NS	NS	NS	4	12	36	NE	0	0	0	7	94	208
NF-14	NS	NS	NS	NS	NS	NS	NS	NE	NS	NS	NS	NS	NS	NS
NF-15	NE	0	0	0	19	15	118	NE	0	0	0	20	22	161
NF-16	NE	NS	NS	NS	0	0	0	NE	0	0	0	20	30	361
NF-16	NS	NS	NS	NS	NS	NS	NS	NE	NS	NS	NS	NS	NS	NS
MW-164	NS	NS	NS	NS	NS	NS	NS	NE	0	0	0	0	0	0
MW-165	NS	NS	NS	NS	NS	NS	NS	1J	1	5	5	20	74	731
MW-166	NS	NS	NS	NS	NS	NS	NS	NE	0	0	0	20	45	478
MW-033	NS	NS	NS	NS	NS	NS	NS	NE	3	12	27	6	190	440
MW-179	NS	NS	NS	NS	NS	NS	NS	1,700	10	1,300	7,020	20	720	1,897
MW-180	NS	NS	NS	NS	NS	NS	NS	1,000	10	1,100	5,190	20	780	3,525

Exceeds benzene criterion (1µg/L)

Contains TICs that are unknown and exceed the interim generic standard for individual TICs (100 µg/L) or total TICs (500 µg/l)

NS Not sampled

NE Does not exceed criterion

Semi-volatile TICs were analyzed in 48 of the 49 samples collected. Of these, tentatively identified semi-volatile compounds were detected in 41 groundwater samples. Of the 41:

- Thirteen were from wells where benzene exceedances had been detected and were not evaluated separately.
- Twenty-eight had TICs that were detected below the NJDEP Interim Organic Criterion of 100 µg/l for individual non-carcinogenic organic compounds and 500 µg/l for total combined organic compounds. There is no evidence of carcinogenicity for these TICs.
- Two samples contained a TIC that exceeded either the individual or total interim generic criteria.

The two samples that contained TICs in excess of the Interim Generic Organic Criterion include:

- MW-124 with an unknown alkane with a retention time of 37 minutes (110 µg/L); and
- MW-126 with two unknowns in excess of 100 µg/L and a total in excess of 500µg/L.

The two unknowns have retention times of 9.2 minutes and 10.3 minutes respectively.

8.2.3.2 Contaminant Distribution – Second Round

Based on the assessment of the fourth quarter 2002 groundwater data, Chevron installed an additional five wells in the North Field/Main Yard. A second round of groundwater sampling and analysis was conducted to confirm the results of the initial effort. The sampling was conducted during the first six months of 2003 and consisted of all wells sampled during the fourth quarter 2002 round except for RW-42, MW-57, MW-65 and MW-133. Added to the sampling program were newly installed wells MW-164, MW-165, MW-166, MW-179 and MW-180, and the sentinel well MW-33 for a total of 51 wells.

RW-42, MW-57 and MW-65 were sampled during the fourth quarter of 2002 as part of the LNAPL Program, and were not re-sampled for the RFI. MW-133 was not re-sampled due to the accumulation of LNAPL.

Of the 51 wells included in the sampling round, groundwater from 45 wells were analyzed for RFI parameters including VOCs, SVOCs and metals. Also included were tests for alkalinity, hardness, chlorides, sulfates, nitrites, nitrates and TDS. The remaining six wells (NF-10, NF-11, NF-12, NF-13, NF-14, NF-15 and NF-16) were analyzed for closure parameters (a limited list of volatile and semi-volatile compounds).

VOC Results

VOCs were detected above the groundwater delineation criteria in 13 of the 51 wells sampled (Figure 8-17). Benzene was responsible for 12 of the 13 exceedances. Benzene was the only VOC detected above the delineation criterion in six of the 12 wells. The only VOC detection without benzene was in MW-164, where 12 µg/L of cis-1,2 dichloroethene was found. In addition, results from MW-117, MW-118, MW-122, MW-179, MW-180 and NF-10 indicated the presence of other VOCs in addition to benzene (Table 8-15). One compound, methyl tert-butyl ether, detected at 220 µg/l in MW117, was never used at the Refinery; therefore, its presence must be attributed to other sources.

Table 8-15. North Field/Main Yard Second Round VOC Results

Compounds (results in µg/L)	MW-117	MW-118	MW-122	MW-179	MW-180	NF-10	
Benzene (Criterion = 1 µg/L)	1,100	15	350	1,700	1,000	790	680
Ethylbenzene (Criterion = 700 µg/L)	NE	NE	NE	920	NE	NE	NE
Methyl t-butyl ether (Criterion = 70 µg/L)	220	NE	NE	NE	NE	NS	NS
Xylene (Criterion = 1,000 µg/L)	NE	NE	NE	3,000	2,300	1,800	1,200
2-methyl-2-propanol (Criterion = 100 µg/L)	320J	NS	NS	NS	NS	NS	NS
1,2-dichloropropane (Criterion = 1 µg/L)	NE	NE	NE	NE	7	NE	NS
Cyclohexane (Criterion = 100 µg/L)	NE	250	120	600	930	720	720J
1,4-Dichlorobenzene (Criterion = 75 µg/L)	NE	NE	NE	NE	NE	NE	NS
Methylcyclohexane (Criterion = 100 µg/L)	NE	NE	NE	270	370	140J	140J

Detected as a TIC which exceeds either known criterion or the interim generic standard for individual TICs (100 µg/L)

NS Not sampled

NE Does not exceed criterion

Nine of the 12 wells that contained benzene exceedances in the first round of sampling were re-sampled in the second round. The presence of benzene was confirmed in all nine wells. Of the nine confirmed exceedances, four wells indicated decreasing benzene concentrations (MW-117, MW121, MW-125 and NF-11) and four wells showed increases (MW-39, MW-122, MW-123 and NF-10). One well (MW-118) exhibited a consistent benzene concentration of 15 µg/l. Benzene was also detected in three additional wells not sampled during the fourth quarter of 2002 (MW-165, MW-179 and MW-180).

MW-180 is a deeper well screened in the first water bearing zone beneath the fill/native interface. The concentrations of VOCs in this well indicate that vertical delineation has not been accomplished in the North Field/Main Yard.

SVOC Results

SVOCs were detected in excess of the groundwater delineation criteria in five of the 49 wells sampled (Figure 8-18). All five detections were for petroleum-related compounds. The presence of phthalates, previously detected in MW-13 and P-4 was not confirmed.

A summary of the detections is included in Table 8-12. Petroleum-related SVOCs were detected in MW-117, MW-121, MW-123, MW-180 and NF-12. Confirmation of the presence of SVOCs in the first round was sporadic:

- The presence of SVOCs in MW-21 was not confirmed in the second round at the method detection level of 1 µg/l.
- MW-65 and RW-42 were not re-sampled, so the detections in the first round could not be confirmed.
- The presence of phenolic compounds in MW-117 was confirmed by the second round sampling.
- While SVOCs continued to be detected in MW-121, different compounds were detected.
- SVOCs were not detected in MW-123 in the first round of sampling.

MW-121 and NF-12, contained PAHs including benzo(a)anthracene and benzo(a)pyrene. These compounds have very low solubilities. The presence of these compounds in the groundwater samples is attributable to their adsorption to fine particles suspended in the sample. TDS was measured in the two samples and was detected at levels exceeding the NJDEP Class IIA GWQC. TDS in MW-121 was measured at 1,280,000 µg/l and in NF-12 at 23,600,000 µg/l. This indicates these compounds are neither dissolved nor mobile in groundwater.

Metals Results

The detection of metals at concentrations exceeding the delineation criteria in the second round of sampling was sporadic (Figure 8-19). Of the 51 wells sampled, only 15 contained metals in excess of the delineation criteria (Table 8-13). The analyte most often encountered was arsenic, followed by thallium and lead:

- Arsenic was detected in excess of the delineation criterion in seven wells ranging in concentration from 8.4 to 31.7 µg/l;
- Thallium was detected in six wells ranging in concentration from 11 to 54 µg/l;
- Lead was detected in four wells ranging in concentration from 15.4 to 73 µg/l; and
- Cadmium was detected in two wells at 6.6 and 24 µg/l.

Of the 15 wells with second round metals exceedances, only three confirm results from the first round. Only the arsenic exceedances in MW-117, MW-118 and MW-122 were confirmed by detections in the second round of sampling.

Tentatively Identified Compounds

Groundwater from the 51 wells sampled in the second round was analyzed for TICs. The compound 4-hydroxy-4-methyl-2-pentanone was again detected in numerous samples and is not included in further analysis of the TICs, as it is a laboratory analysis artifact.

Volatile TICs were found in 22 of the 51 samples analyzed (Table 8-14). Of these, 12 were associated with wells where benzene exceedances had been detected, so no further TIC-specific evaluation was conducted. The remaining ten samples do not contain any identifiable compounds that exhibit evidence of carcinogenicity, and they were detected at levels below the NJDEP Interim Generic Individual Organic Criterion of 100 µg/l and the Combined Total Organic Criterion of 500 µg/l.

Tentatively identified SVOCs were detected in 43 of 51 groundwater samples. Of the 43:

- Twelve were from wells where benzene exceedances had been detected and were not evaluated specifically;
- Twenty-six contained TICs without evidence of carcinogenicity and were detected below the NJDEP Interim Generic Organic Criterion of 100 µg/l for individual compounds and 500 µg/l total combined organic compounds; and
- Five samples contained TICs that either individually exceeded 100 µg/l or all TICs combined exceeded 500 µg/l.

P-2, MW-3, NF-12, NF-13 and MW-33 exceeded the Interim Generic Organic Criterion as discussed below:

- The samples collected from P-2, NF-12 and NF-13 in the first round did not exceed the Interim Generic Standards. The second round indicated the following:
 - P-2 - contained one “unknown” TIC at a concentration of 110 µg/l with a retention time of 3.381 minutes;
 - NF-12 - contained one “unknown” TIC at a concentration of 110 µg/l with a retention time of 30.57 minutes. NF-12 also contained 25 semi-volatile TICs totaling 936 µg/l with retention times ranging from 29 to 45 minutes; and
 - NF-13 - contained one “unknown” TIC at a concentration of 1,600 µg/l with a retention time of 22.275 minutes.
- The sample from MW-33 contained one compound identified as “phenazine” (without a CAS#) at an estimated concentration of 190 µg/l and with a retention time of 24.83 minutes.

- MW-3 is the only well where TICs in excess of the interim generic standard were detected in both rounds. Both samples contained “unknowns” in excess of the standard with retention times of 11.826 and 10.095 minutes, respectively.

8.2.4 Data Analysis

Based on the two rounds of groundwater sampling and analysis conducted to date, Chevron has determined that further assessment of the North Field/Main Yard groundwater relating to VOCs and SVOCs should be focused on benzene as the primary contaminant of concern. This determination has been made for the following reasons:

- Benzene is the most broadly distributed VOC;
- Benzene is a carcinogen with the most stringent delineation criteria of the detected organic compounds;
- Other VOCs were not detected without the presence of benzene with the exception of cis-1,2-dichloroethene at 12 µg/l in MW-164;
- Petroleum based SVOC exceedances are collocated in wells with benzene, with the exception of low levels of benzo(a)pyrene and benzo(a)anthracene in two wells;
- Benzene is expected to be the focus of the CMS;
- Benzene is soluble in groundwater and its fate and transport characteristics are well known; and
- Benzene is representative of the light end of the refining process, the presence of which is consistent with the refining history of the site.

The benzene exceedances in the North Field/Main Yard ranged in concentration from 1 to 1,900 µg/l. These detections appear to be associated with seven distinct and separate dissolved phase plumes.

The boundaries of these plumes are presented on Figure 8-16. The areas to be discussed are as follows:

- Area NF4/NF5/NF6;
- Area MY-1 (AOC 33 and 34);
- Area NF2;
- Area NF3 (AOC 9 and SWMU 20);
- Area MY3 (AOC 19);
- SWMA 1; and
- Area MY2.

The data accumulated from hydropunches and temporary well points will also be discussed.

8.2.4.1 Area NF4/NF5/NF6

The benzene plume in this study area is fairly broad in extent as shown on Figure 8-16. The plume may have originated from several sources including LNAPL Area 5, TEL burials including SWMUs, 6, 16, 17 and 18, and SWMU 35 (the old No. 4 Separator). The plume is defined by benzene exceedances in MW-117, MW-118, MW-122, MW-125, RW-42 and numerous hydropunch/temporary well point samples. The temporary well points were installed as part of the 1st-Phase RFI in 1997 and the OWSS Investigation in 1999. Benzene detections in these groundwater samples ranged from 3 µg/l in H0337 to 11,000 µg/l in HP0100.

In the fourth quarter 2002 sampling event, benzene was detected in:

- MW-117 at 1,900 µg/l;
- MW-118 at 15 µg/l;
- MW-122 at 290 µg/l;
- MW-125 at 800 µg/l; and
- RW-42 at 2 µg/l.

In the second round of samples collected in 2003, benzene was detected in:

- MW-117 at 1,100 µg/l;
- MW-118 at 15 µg/l;
- MW-122 at 350 µg/l; and
- MW-125 at 19 µg/l.

RW-42 was not sampled in the second round.

It should be noted that MW-125, RW-42 and MW-118 were placed in close proximity to earlier hydropunch samples HP-0083, HP-0100 and HP-0082, respectively. The hydropunch samples were collected in 1997 and showed higher levels of benzene in the groundwater. In the southern or most upgradient portion of the plume, benzene was detected at 11,000 µg/l in HP-0100. Five years later in RW-42, benzene was detected at 2 µg/l. In the eastern portion of the plume, benzene was detected at 4,200 µg/l in HP-0083. Six years later in MW-125, benzene was detected at 19 µg/l. In the vicinity of SWMU 6, benzene was detected at 120 µg/l in HP-0082. Six years later in MW-118, benzene was detected at 15 µg/l. Of the five wells monitored within this plume, only MW-117 and MW-122 have shown consistent exceedances of benzene over the six-year period since the 1st-Phase RFI for groundwater.

Groundwater flow is generally to the north-northeast towards Woodbridge Creek. However, groundwater elevation data indicates a localized reversal of flow along the property boundary with Woodbridge Creek (Figure 8-10). During the recent period of normal to high precipitation, the groundwater has been measured very near the surface in the wells located in tank basins in this area. When mapped, a depression in the water table centered around Tanks 327 and 301 is apparent. The depression may be the result of pumping storm water from the OWSS out of the Basin and up to the ETP. This effect is enhanced by the underlying depression in the clay/peat layer caused by compaction of the peat. The combined effects appear to be causing groundwater to flow into this area.

Downgradient migration monitoring for this plume is provided by nine sentinel wells (MW-30, MW-31, MW-32, MW-124, MW-33, MW-126, MW-136, MW-34 and MW127). Sentinel wells MW-30, MW-31, MW-32, MW-33 and MW-34 have been sampled numerous times over the past three years with only one recorded slight exceedance of the delineation criteria for VOCs (MW-32 at 1.3µg/L of benzene). Monitoring of the concentrations within the plume will be provided by MW-122, MW-117, MW-118, MW-125 and RW-42. Upgradient delineation of this plume is provided by MW-24, MW-128 and MW-139. P-1 will be added to the monitoring program as an upgradient well. The wells are all screened in the shallow water zone in the fill.

The gradient in this area averages approximately 0.01 ft/ft based on measurements of groundwater elevations in MW-134, MW 43 and MW 158 (Table 8-16).

Table 8-16. NF4/NF5/NF6 Gradients

Well	Well	Distance (feet)	Elevation Change (feet)	Gradient
RW-42	MW-117	470	4.25	0.009
RW-42	MW-34	410	5.81	0.014

The boring logs in this area indicate the fill is variable. Towards the south, the primary component is sand, but in the vicinity of Tank Basins 300, 301, 326 and 327, the primary components are silts and clays. The peat/clay zone appears to be present beneath the entire area of this benzene plume limiting vertical migration.

Using conservative estimated values for hydraulic conductivity and published values for effective porosity for the sands, clays and silts indicated on the boring logs, an average groundwater velocity has been calculated as follows:

$$Velocity = \frac{Hydraulic\ Conductivity \times Gradient}{Porosity_{(effective)}}$$

$$Velocity = \frac{(1 \times 10^{-4} \text{ cm/sec}) \times (0.01)}{0.15}$$

$$Seepage\ Velocity \approx 7 \text{ ft/yr}$$

Given that there is little data indicating that VOC contamination has reached the sentinel wells in this area, the low seepage velocity, and the evidence that VOC concentrations have been declining over the past five years, Chevron proposes continued monitoring of the 16 wells associated with this plume for a minimum of six additional rounds of sampling to determine if the apparent decreasing trend in benzene concentrations in the groundwater can be confirmed. The groundwater samples collected will be analyzed for volatile compounds, semi-volatile compounds, arsenic and lead. MW-128, RW-42, MW-139, P-1, MW-122, MW-117, MW-125, MW-127, MW-34, MW-126, MW-33, MW-121, MW-32, MW-31, MW-136 and MW-30 will be included in the monitoring program.

8.2.4.2 Investigation Area MY1 (AOCs 33 and 34)

The benzene plume in this area appears to extend from Tank Basin 314 downgradient into Tank Basin 315 (Figure 8-16). This AOC was initially identified based on a release of petroleum from Tanks 314 and 315. The material managed in Tank 314 at the time of the release was rheniformer stock that ultimately would be processed into gasoline. Groundwater sampling during the OWSS Investigations indicated the presence of benzene at concentrations as high as 200 µg/l in the southern portion of Tank Basin 314. Additional OWSS Investigation groundwater samples from Tank Basin 315 indicated the presence of benzene at concentrations of up to 100 µg/l.

In the initial stages of the RFI, two wells were added to the existing monitoring network in this area. One of the new wells, MW-112, was placed downgradient of the benzene detections identified in Tank Basin 314 and was screened across the first water bearing zone. The other new well, MW-159, was also screened across the shallow water bearing zone and was placed in the northern portion of Tank Basin 315. These two wells, in conjunction with existing wells MW-3 and the P-4, P-5 and P-6 cluster, provided groundwater monitoring for this area.

During the fourth quarter 2002 groundwater sampling, no volatile or semi-volatile compounds were detected in any of the wells identified to monitor this area except 45 µg/l of bis(2-ethylhexyl)phthalate in P-4. The phthalates detected in P-4 are common contaminants associated with sample handling procedures and are not evaluated further.

Subsequent to the first round of samples, Chevron determined the need for an additional well. MW-179 was installed in the northeast corner of Tank Basin 314 and was screened across the shallow water bearing zone. The results of the second round of groundwater sampling conducted during the first half of 2003 were the same for the wells sampled during the fourth quarter of 2002; there were no detections of volatile or semi-volatile compounds in excess of the criteria. The groundwater sample from MW-179 indicated the presence of benzene (1,700 µg/l), cyclohexane (600 µg/l), ethylbenzene (920 µg/l), methylcyclohexane (270 µg/l) and xylene (3,000 µg/l). These compounds are consistent with the reported release of rheniformer stock from Tank 314.

The groundwater flow in the shallow water table in this area is to the northeast and gradients are low. The gradient measured between MW-112 and RW-21 in Tank Basin

328 is 0.01 ft/ft. The gradients in the immediate vicinity of Tank Basins 314 and 315 are less than 0.01 ft/ft. The boring logs indicate the fill is directly underlain by the reddish brown till in the vicinity of Tank Basin 314. The upper section of the till in this area is described primarily as a sandy clay. To the northwest, in the vicinity of Tank Basin 315, a one to two foot thick grey micaceous clay is evident directly beneath the fill. This grey clay is underlain by the reddish brown till. The fill itself is highly variable and consists of debris, sands, silts and clays.

The benzene plume associated with AOCs 33 and 34 will be monitored by MW-179. Upgradient monitoring of this plume is provided by P-4, MW-12 and MW-138. The southern plume edge is defined by MW-112 and MW-3. The northern and downgradient monitoring of the benzene is provided by MW-159.

Using conservative estimated values for hydraulic conductivity and published values for effective porosity for the sands, clays and silts indicated on the boring logs, an average groundwater velocity has been calculated as follows:

$$Velocity = \frac{Hydraulic\ Conductivity \times Gradient}{Porosity_{(effective)}}$$

$$Velocity = \frac{(1 \times 10^{-4} \text{ cm/sec}) \times (0.01)}{0.15} \qquad \text{Seepage Velocity} \approx 7 \text{ ft/yr}$$

Since Tanks 314 and 315 have been taken out of service and cleaned, there is no further potential for additional releases in this area. Given the low seepage velocity and the distance to any off-site receptor, Chevron proposes to monitor the levels of benzene in this area at MW-3, MW-112, MW-159 and MW-179 for seven additional sampling events to establish contaminant trends and to determine if the area impacted by benzene is decreasing in size. The groundwater samples collected from these wells will be analyzed for VOCs only.

8.2.4.3 Area NF2

The dissolved phase benzene plume in this area is defined by exceedances in well NF-11 and several hydropunch/temporary well point groundwater samples collected as part of the 1st-Phase RFI for groundwater and the OWSS Investigations (Figure 8-16). NF-11 has been a part of the Closure Project monitoring for the NFB and Surge Pond projects for many years. Benzene has been detected in this well for an extended period of time. During the OWSS Investigation, LNAPL was detected in several temporary well points that triggered a separate LNAPL Investigation. The details of the LNAPL Investigation are included as Section 7 of this report. In summary, LNAPL is actively being recovered from this area and it appears that the dissolved benzene plume is emanating from the LNAPL. It is believed that the presence of LNAPL is due to a release of material managed in Tank 329. This conclusion is based on similarities between the LNAPL and material historically only stored in Tank 329, as no record of such a release has been found.

In general, there is six to 15 feet of fill overlying native materials in this area (Cross Section D-D', Figure 8-14). Clay Horizon A is only one to two feet thick and is discontinuous.

As part of the initial RFI effort, four wells were installed in the vicinity of LNAPL Area NF2. MW-114 and MW-115 were installed as a nested pair to identify groundwater impacts from SMWU 28 (Reactor Burial). MW-114 was screened from two to twelve feet bgs across the first water bearing zone. MW-115 was screened in the second water bearing zone from 17 to 22 feet bgs in a sandy zone in the till.

In the vicinity of the reactor burial, the till is separated from the fill by a one-foot thick grey clay. Both wells were sampled twice and no constituents exceeding the criteria were identified.

MW-116 was installed in the southeast corner of Tank Basin 312. The location was selected to monitor groundwater conditions downgradient of SWMA 2 and SWMU 53 (potential discharge to Tank Basin 312). LNAPL was encountered during installation of this well and the area became subject to additional activities under the LNAPL program. Extensive investigation of the LNAPL has been conducted and is reported in Section 7 of this report.

MW-120 was installed to monitor groundwater conditions downgradient of SWMU 22 (TEL Burial). The well is screened in the fill and partially in the underlying till. At the time the water level data was collected, Tank Basin 329 held standing water. The data collected from MW-120 indicated that the water level elevation in the well was above the ground surface and in the well casing. Groundwater samples were collected from this well during both rounds of sampling. No constituents were identified in either round that exceeded the criteria, except for one detection of thallium at 13.8 µg/l. This detection was not confirmed during the second round of sampling.

In addition to the recently installed wells, MW-20, MW-2 and NF-11 were sampled to determine the quality of the groundwater in this area. As already discussed, NF-11 has a history of elevated concentrations of benzene. MW-20 and MW-2 are located along the western property boundary and are screened in the shallow groundwater zone. Both wells were sampled twice and no constituents exceeding the criteria were identified except for arsenic in MW-20. Arsenic was detected at an estimated concentration of 9.6 µg/l during the first round (fourth quarter of 2002) of sampling. This exceedance was not confirmed during the second round collected during the first half of 2003.

The limits of dissolved phase groundwater impacts from the LNAPL in this area are delineated by the clean zones identified in MW-120, MW-57, MW-20, MW-114/115 and MW-2. Ongoing monitoring of the dissolved benzene concentrations is provided by NF-11.

Locally, groundwater flow appears to be towards the Tank Basin 312 area (Figure 8-10). Stormwater flows by way of gravity from the adjacent tank basins into Tank Basin 312.

A sump in Tank Basin 312 pumps stormwater to the ETP. This may have an impact on the shallow groundwater table resulting in the low groundwater elevation evident in MW-116. Additionally, groundwater flow is affected by the sheet pile placed along the southern edge of the NFB. The sheet pile has had a damming effect on the shallow groundwater, causing a local reversal in the regional groundwater flow direction.

Gradients in this area are fairly low. The gradient measured between MW-116 and NF-11 is slightly less than 0.01 ft/ft. The gradient measured between RW-2 and MW-116 is slightly greater than 0.01 ft/ft. Using conservative estimated values for hydraulic conductivity and published values for effective porosity for the sands, clays and silts indicated on the boring logs, an average groundwater velocity has been calculated as follows:

$$Velocity = \frac{Hydraulic\ Conductivity \times Gradient}{Porosity_{(effective)}}$$

$$Velocity = \frac{(1 \times 10^{-4} \text{ cm/sec}) \times (0.01)}{0.15}$$

$$Seepage\ Velocity \approx 7 \text{ ft/yr}$$

In this area, there may be a continuing source of benzene and other VOCs to groundwater from the NF2 LNAPL Area. However, based on the data collected to date, it appears the dissolved phase plume emanating from the LNAPL is contained, as shown by the clean zone wells. Since the LNAPL is now being actively recovered, Chevron proposes to continue to monitor the dissolved phase plume for an additional six rounds of sampling to establish trends in the concentration of benzene. The sampling events will include MW-114, RW-02, NF-11, MW-120, MW-057, and MW-20. MW-116 will be added to the sampling schedule when LNAPL removal efforts are complete. Groundwater samples collected from these wells will be sampled for volatile constituents only.

8.2.4.4 Area NF3 (AOC 9 and SWMU 20 - TEL Burial)

This dissolved phase benzene plume encompasses most of Tank Basins 303 and 302 (Figure 8-10). The RFI was focused on determining the extent of the dissolved benzene that has been detected in NF-10. NF-10 has been part of the Closure Project monitoring, and benzene has been detected in this well for an extended period of time. Benzene has also been detected above criteria in several hydropunches and temporary wells installed as part of previous investigations. Also included in this area is a suspected TEL Burial (SWMU 20) in the eastern portion of Tank Basin 302.

Initially, MW-123 was installed in what was believed to be a downgradient location from SWMU 20. MW-123 is screened in the fill and partially in the underlying till. The fill at this location is primarily made up of sandy material. Immediately below the fill is a 2.5-foot thick clay/peat zone underlain by till. The till at this point is primarily composed of a stiff, red-brown clay (Figure 8-13, Cross Section C-C').

NF-10, which was installed in 1992, encountered significantly different subsurface conditions. The initial boring went to 14 feet bgs and the well was screened from three to 13 feet bgs. The boring log indicates fill down to 12 feet where a light grey silty clay was encountered. It appears the expected clay/peat layer and red-brown till are missing from this section. It is believed that NF-10 was installed in an old channel feature that was backfilled with a variety of coarse-grained material.

Due to the nature of the fill encountered in NF-10, it was determined that a double cased well screened in the second water bearing zone would be necessary. The well, MW-180, was placed adjacent to NF-10 and steel casing was driven into a two-foot thick grey clay encountered immediately below the fill at approximately 15 feet bgs. The casing was cemented into place. The well was advanced into a seven-foot thick light gray sand immediately below the gray clay. Near the base of the boring, a gray to red brown clay was encountered followed by red-brown sand and gravel which are consistent with the till. The well was screened from 17 to 27 feet bgs.

NF-10 was sampled three times during the course of the RFI, MW-123 was sampled twice and MW-180 was sampled once. In the first round collected during the fourth quarter of 2002, benzene was detected in excess of the criterion in NF-10 and MW-123. Xylene was also detected in excess of the criterion in NF-10. Semi-volatile compounds were not detected in either well. In the first half of 2003, the following results were recorded for the three wells (Table 8-17).

Table 8-17. NF-10, MW-180 and MW-123 Results

Compound (results in µg/l)	NF-10 (01/03)	NF-10 (04/03)	MW-180	MW-123
Benzene (Criterion = 1 µg/L)	680	790	1,000	290
Xylene (Criterion = 1000 µg/L)	1,200	1,800	2,300	NE
Cyclohexane (Criterion = 100 µg/L)	NS	720J	930	NE
Methylcyclohexane (Criterion = 100 µg/L)	NS	140J	370	NE
2,4-Dimethylphenol (Criterion = 100 µg/L)	NS	NE	280	620
2-Methylphenol (Criterion = 100 µg/L)	NS	NS	110	NE
Lead (Criterion = 10 µg/L)	NE	NE	NE	30.2
Thallium (Criterion = 10 µg/L)	NS	NS	13.2J	NE

Detected as a TIC which exceeds known criterion

NS Not sampled

NE Does not exceed criterion

J Estimated concentration

A specific source for the constituents detected in the groundwater has not been identified. The tanks in this area were used for storage of gasoline stock and products, and there is the possibility that small releases from these tanks over time contributed to the present condition of the groundwater. These materials are no longer managed at the Refinery and the tanks have been cleaned. It is also possible that this plume is associated with the releases described for AOC 33. The constituents encountered are similar, and AOC 33 is upgradient of AOC 9b and SWMU 20. SWMU 20 is believed to be the source of the lead detected in MW-123.

Locally, shallow groundwater flow appears to be towards Tank Basins 302 and 330 (Figure 8-10). Stormwater flows by way of gravity from the adjacent tank basins into Tank Basin 302. A sump in Tank Basin 302 pumps stormwater to the ETP. This may have an impact on the shallow groundwater table resulting in the low groundwater elevation evident in MW-123 and MW-72. Additionally, groundwater flow is affected by the sheet pile placed along the southern edge of the NFB. The sheet pile has had a damming effect on the shallow groundwater, causing a local reversal in the regional groundwater flow direction.

The dissolved phase plume detected in the shallow groundwater is delineated to the extent necessary:

- MW-120 defines the clean zone to the northwest;
- The SWMU 43 LNAPL recovery system is located to the northeast;
- Benzene was not detected in H0322 and H0317 to the southeast; and
- A separate dissolved phase plume is located to the southwest.

Gradients in this area are fairly low. The gradient measured between MW-140 and NF-11 is slightly greater than 0.01 ft/ft. The gradient measured between MW-70 and MW-72 is less than 0.01 ft/ft. Using conservative published values for hydraulic conductivity and effective porosity for the sands, clays and silts indicated on the boring logs, an average groundwater velocity has been calculated as follows:

$$Velocity = \frac{Hydraulic\ Conductivity \times Gradient}{Porosity_{(effective)}}$$

$$Velocity = \frac{(1 \times 10^{-4} \text{ cm/sec}) \times (0.01)}{0.15}$$

$$Seepage\ Velocity \approx 7 \text{ ft/yr}$$

Based on the presence of COCs below the clay-peat interval in this area and the potential for downward migration through the sediments identified in MW-180 and NF-10, Chevron has determined that additional investigation activities are required. These activities will be conducted after the submittal of this report. A report recounting the activities conducted and the results will be submitted as an addendum to the RFI. The

goal of the investigation will be to determine the extent of the contamination detected in MW-180.

During the period of additional investigation, continued monitoring of MW-123, MW-120 and NF-10 will be conducted. Groundwater samples will be analyzed for VOCs, SVOCs and lead. Chevron intends to abandon MW-180 because it is potentially screened across two separate water-bearing zones. Once the additional investigation is complete, wells will be installed to properly monitor the water bearing zones of concern.

8.2.4.5 Area MY3 (AOC 19)

This area contains a small benzene plume with low concentrations and is of minimal concern. The area was initially identified during the installation of PZ-12 when LNAPL was encountered, and it is believed that the LNAPL is the source of the benzene. The LNAPL investigation that was conducted in this area is reported in Section 7 of this report. The benzene plume is defined by low level concentrations encountered in a few groundwater samples collected from temporary well points and one sample from MW-133. The highest concentration of benzene (860 µg/l) was encountered in H0303 that was installed as part of the OWSS Phase II Investigation in 1999. No other VOCs or SVOCs were detected in excess of the criteria. MW-133 was installed in close proximity to H0303 and was sampled in 2002 as part of the LNAPL Investigation. Benzene was detected at an estimated concentration of 2 µg/l. The plume is substantially delineated by H0453 to the east, H0415 to the west, H0130 to the south and MW-128 to the north.

Chevron does not feel this area warrants further consideration from the perspective of significant groundwater impacts. LNAPL is actively being removed from the subsurface, and this plume is directly upgradient of the Investigation Area NF4/NF5/NF6 plume that is being monitored. Chevron does propose, however, to collect groundwater samples from MW-133 and MW-128 for VOC analysis. Sampling will be conducted for seven additional periods to determine contaminant trends.

8.2.4.6 SWMA 1

This area contains a group of units that are identified as SWMUs due to the historic management of various wastes. SWMU 39, the Unnamed North Field Pond, appears to be the most important from the perspective of groundwater impacts. Aerial photos and Refinery records indicate this area has been used as a fluids retention and sludge drying area in the past. Subsequently, the area was backfilled with as much as 20 feet of fill (MW-121). It appears some of the residual tar-like material was incorporated in the fill and now appears as stringers and globules of viscous material in the groundwater. This tar-like material has periodically been observed in MW-13 during the 12 years since it was installed. Groundwater is found approximately two to five feet below the surface perched on the native clay/peat surface.

Locally, low-levels of benzene dissolved in the groundwater appear to be emanating from the tar-like material. The dissolved benzene in SWMA 1 was initially identified in two

hydropunch samples collected during the 1st-Phase RFI for Groundwater. Benzene was detected at 84 µg/l and 3 µg/l in H0158 and H0159, respectively. As part of the initial RFI effort, one well, MW-121, was installed in this area to confirm the presence of constituents in the groundwater in the central portion of SWMA 1. In the first round of sampling during the fourth quarter of 2002, benzene was detected at 10 µg/l in MW-21. The only other exceedances of the criteria were an estimated 8 µg/l of chrysene in MW-121 and 2 µg/l of benzo(a)pyrene and 2 µg/l of benzo(a)anthracene in MW-21.

In response to the first round results, Chevron added three wells (MW-164, MW-165 and MW-166) to the perimeter monitoring system. These wells are all screened in the shallow water table. During the second round of groundwater sampling, all wells in SWMA 1 were sampled. The only exceedance of the VOC delineation criteria was benzene at estimated concentrations of 3 µg/l and 1 µg/l in MW-121 and MW-165, respectively. Also detected was cis 1,2-dichloroethene (12 µg/L). The SVOCs previously identified in MW-21 were not detected in the second round of sampling. Chrysene, observed in the first round sample from MW-121, was not detected in the second round, although benzo(a)pyrene and benzo(a)anthracene were detected at estimated concentrations of 3 µg/l.

The fill used to raise and level the ground surface in SWMA 1 is highly variable, but is primarily composed of clays and silts. There are, however, discontinuous sands of two to five feet in thickness in some of the filled areas. The fill varies in thickness from approximately 10 feet to as much as 20 feet. Beneath the fill, the boring logs indicate the clay/peat interval is continuous. Even where the fill is thickest (i.e., MW-121), the clay/peat is evident at the base of the boring.

Groundwater flow is primarily to the northeast in SWMA 1; however, due to the highly variable nature of the fill, it appears that in the southern half of SWMA 1 there may be a localized reversal in the groundwater flow direction. Through two rounds of depth to groundwater readings, the elevation of the groundwater table in MW-121 and MW-20 has been unexpectedly high. In MW-121, this can be explained by a six-foot clay interval in the fill from six to twelve feet bgs that has caused groundwater to be perched above the native/fill interface. The boring log for MW-20 only indicates miscellaneous fill through this section; however, the same conditions may exist here as well.

Regardless of the potential for a reversal in the groundwater flow direction, the minimal concentrations of dissolved benzene are delineated by the existing wells. If, in fact, there is a groundwater flow component transporting benzene to the south, it apparently did not reach the locations in the northwest corner of Tank Basin 312 where several groundwater samples were collected and benzene was not detected. Further to the east, any migration of constituents would commingle with the LNAPL and benzene plumes found in Area NF-2. The only results that are of limited concern are the detection of benzene at 1 µg/l in MW-165 and the 12 µg/l of dichloroethene identified in MW-164. These results will be confirmed or not confirmed in the next round of samples.

Chevron proposes to continue to monitor the low levels of VOCs that have been identified in wells in this area (MW-21, MW-121, MW-164, MW-165, and MW-166). If the low levels of benzene persist, then six additional sampling events will be conducted to determine contaminant trends. If the levels of benzene and/or other constituents fall below the delineation criteria for two consecutive rounds, the sampling will be discontinued. The groundwater samples will be analyzed for VOCs and SVOCs.

8.2.4.7 Area MY2

The plume in this area is defined by the low concentration of benzene detected in MW-39 during the first and second sampling events. Benzene was the only constituent detected in excess of the criteria during either round. In addition to the MW-39 results, there have been several low concentration detections of benzene in surrounding hydropunch samples and one significant detection of benzene (21,000 µg/l) in H0435.

The source of the benzene in the groundwater is unknown; however, it is assumed that it may have migrated from the OWSS. Historically, gasoline stock was managed and processed in this area and the high benzene concentration detected in H0435 was from a location immediately adjacent to the OWSS. It is also apparent from the H0435 boring log that flyash containing black liquid globules was noted immediately above the fill native/interface (Figure 8-12, Cross Section B-B'). In other locations within the Refinery, similar conditions have been observed. Gasoline products are no longer managed in this area and the tanks have been cleaned, so the potential for ongoing or additional releases has been eliminated.

As part of the initial RFI effort, three additional shallow monitoring wells were installed in this area. MW-140 was placed in an apparent downgradient location, while MW-137, MW-138 and MW-139 were placed upgradient and near the Crude Unit in an attempt to determine the location of the source of benzene in MW-39.

Groundwater samples were collected from the seven wells (MW-3, MW-112, MW-140, MW-137, MW-138, MW-139 and MW-39) that are being used to define the benzene plume in this area during both sampling events. Of these seven wells, only MW-39 contained benzene in concentrations exceeding the criteria. No other volatile or semi-volatile compounds were detected in excess of the criteria. There were scattered detections of arsenic, lead and thallium in samples from these wells, but none of the detections were confirmed by both rounds of samples.

The limits of the benzene plume are well defined by the existing wells (Figure 8-10). In general, groundwater flow in this area is to the east-northeast and MW-140 and MW-139 are downgradient of the plume. MW-137, P-3 and MW-112 are sidegradient and MW-138 is in a relative upgradient location. The upgradient direction is difficult to determine since the groundwater elevation in MW-39 is higher than any of the surrounding wells, suggesting radial flow away from the well. Regardless of the flow direction, MW-39 is surrounded by "clean" wells.

The fill in this area varies from seven to ten feet in thickness and is predominately described as sandy with a significant clay component. The fill overlies the peat/clay interval that is two to four feet thick and appears to be continuous throughout the area described by the plume, limiting vertical migration. Beneath the peat/clay zone are the red-brown sands, silts and clays of the till.

The maximum gradient is measured between MW-39 and MW-139 at approximately 0.015 ft/ft. Using conservative published values for hydraulic conductivity and effective porosity for the sands, clays and silts indicated on the boring logs, an average groundwater velocity has been calculated as follows:

$$Velocity = \frac{Hydraulic\ Conductivity \times Gradient}{Porosity_{(effective)}}$$

$$Velocity = \frac{(1 \times 10^{-4} \text{ cm/sec}) \times (0.015)}{0.15} \qquad \text{Seepage Velocity} \approx 10 \text{ ft/yr}$$

Based on the confirmed presence of benzene in MW-39, Chevron proposes to continue to monitor the wells in this area (MW-3, MW-112, MW-140, MW-137, MW-138, MW-139, MW-39) for an additional six rounds of sampling to determine contaminant trends. In addition, Chevron proposes to install and monitor a shallow well in the location of H0435 to determine whether or not LNAPL is present and if the liquid contained in the flyash may be an ongoing source of groundwater contamination. Groundwater samples will be analyzed for VOCs only.

8.2.4.8 Miscellaneous Temporary Well Points and Hydropunch Samples

During the completion of the Phase II OWSS Investigation, a large number of groundwater samples were collected in the shallow fill zone. Of those samples that indicated the presence of benzene in excess of the criteria, many are incorporated into the plumes described in this section. There are several locations, however, where benzene was detected in excess of the criteria, but are not included in a specific plume area. Of these locations, all are upgradient of identified benzene plumes and all detections were less than 50 µg/l. Chevron believes that the monitoring program that has been proposed adequately addresses the dissolved phase benzene that is incorporated in defined plumes and the scattered low-level concentrations represented by the detections outside of the plume limits.

8.3 Central Yard

The assessment of the Central Yard groundwater conditions is based on data collected from a total of 20 wells, one temporary well, and one piezometer that were installed as part of the RFI or previous investigations. The wells used in the assessment of groundwater in the Central Yard as well as the location of the cross section are shown on Figure 8-20. They include the following:

- Pre RFI wells – two shallow;
- LNAPL Investigation wells – four shallow and one shallow temporary well; and
- RFI – 13 shallow and one deep.

Shallow wells are screened across the water table. The one deep well, MW-169R, is double cased and screened in the first water bearing zone beneath the fill/native interface. Two rounds of water level measurements have been collected as well as two rounds of groundwater samples from most wells. In this section, the surficial geology of the Central Yard, the results of the groundwater investigation and the distribution of contaminants in the Central Yard groundwater will be discussed.

A supplemental investigation has also been conducted in the southern portion of the Central Yard in response to the recent detection of chlorinated organic compounds in MW-44. The supplemental investigation consisted of numerous borings conducted using a geoprobe fitted with a cone penetrometer (CPT) and a membrane interface probe (MIP). The details of this investigation and the results are presented as Appendix G to this report.

8.3.1 Geology

The Central Yard is composed of varying amounts of fill overlying a gray clay and glacial till. The data shows the top of the water table is in the fill layer perched on the native clay and till. The fill contains varying amounts of sand, gravel and debris but is primarily composed of silts and clays as shown on the cross section in Figure 8-21.

Immediately beneath the fill in the northern two thirds of the Central Yard is a dark gray clay (Clay Horizon A). This clay is evident in boring logs from MW-44 to the northern limits of the Yard. Clay Horizon A is described as a light gray to black organic marine deposit with minor amounts of sand and gravel. This clay can be as much as 20 feet thick in the Central Yard.

In the southern portions of the Yard, the dark gray clay grades into a reddish-brown clay that appears to be the remnants of glacial moraine deposits. The native surface from MW-102 appears to slope steeply to the south towards MW-167 and MW-169R. The fill in this area is as much as 20 feet thick and in some areas directly overlies a reddish-brown sand. This sand is the stratigraphic equivalent of Sand Horizon A. This sand has been described as an erosional remnant of the Old Bridge Sand, but locally, it may in fact be a component of the glacial till. While data indicates this sand is discontinuous, the eastern extent has not been defined.

Further to the south, the boring logs indicate the native material is a gray clay that is consistent with local deposits that are marine in origin (i.e., Clay Horizon A).

Beneath both Clay Horizon A and Sand Horizon A, borings from the Woodward Clyde investigation and the recent CPT investigation indicate a massive clay (i.e., Clay Horizon

B), which is identified as the Woodbridge Clay Member of the Raritan Formation. In the Central Yard, existing data indicates this clay is as much as 40 feet thick and directly overlies the Farrington Sands.

8.3.2 Hydrogeology

The shallow groundwater in the Central Yard is found unconfined in the fill material, perched on the native clay and till. On April 2, 2003 groundwater elevations were measured in 16 wells. The elevation data is presented on Figure 8-20. As shown, a change in the overall flow direction of groundwater is evident in the middle of the Central Yard. Groundwater to the north of MW-108 flows predominately to the north-northeast while groundwater to the south of MW-108 flows predominately to the southeast. In the extreme southern portion of the Central Yard (i.e., south of the Garretson Avenue right-of-way), groundwater flows to the north-northeast causing a confluence in the vicinity of MW-170. From this point, groundwater in the shallow interval flows to the east towards the Arthur Kill.

Gradients measured across the Central Yard vary significantly from the northern portion of the site to the southern portion. In the north, gradients range from 0.01 ft/ft to as high as 0.03 ft/ft (measured between PZ-16 and MW-133). The higher gradients are due to the topographical differences between the Central Yard and the Main Yard. The ground surface in the northern portion of the Central Yard is about 28 feet above MSL while the ground surface in the Main Yard tank basins along Maurer Road are only nine feet above MSL.

Gradients in the southern portion of the Central Yard are less than 0.01 ft/ft except in the immediate vicinity of the Garretson Avenue right-of-way. In this area, the native surface dips steeply to the south and is mirrored by the shallow groundwater surface. Gradients measured between MW-168 and MW-170 approximate 0.03 ft/ft.

For the purposes of the RFI, hydraulic conductivities were not measured by aquifer test in the Central Yard. The materials used for fill and the native materials are similar in nature to those found in the East Yard and the North Field. Therefore, Chevron has selected 1×10^{-4} cm/sec as representative of the site conditions.

Published values (Fetter, 1988) for estimated effective porosity of unconsolidated materials similar to the Central Yard fill have been used. The estimates of conductivity and effective porosity, and the measured gradients have been used to estimate seepage velocities for groundwater in the vicinity of the dissolved contaminant areas found in the Central Yard. The published values used are presented in Table 8-18.

Table 8-18. Central Yard Soil Parameters

Fill Material	Estimated Hydraulic Conductivity	Estimated Effective Porosity
Sand	1×10^{-2} cm/second	25%
Silty Sand, Fine Sand	1×10^{-3} cm/second	20%
Silt, Sandy Silt, Clayey Sand	1×10^{-4} cm/second	15%
Silty Clay	1×10^{-5} cm/second	12%
Clay	1×10^{-6} cm/second	10%

In general, seepage velocities of groundwater appear to be fairly low except in the extreme northern portions of the Yard and near the Garretson Avenue right-of-way. This is primarily due to the variation in the gradient.

8.3.3 Groundwater Chemistry

8.3.3.1 Contaminant Distribution- First Round

During the fourth quarter of 2002, a round of groundwater samples was collected from the existing Central Yard monitoring well system. A total of 12 wells were sampled during this period. Groundwater samples collected from the 12 wells were analyzed for RFI parameters that include VOCs and SVOCs; 11 were also sampled for total metals using the NJDEP approved low-flow sampling technique. MW-104 was analyzed for VOCs and SVOCs only. A library search for TICs was conducted for all samples.

VOC Results

VOCs were detected above the delineation criteria (NJDEP Class IIA GWQC) in four (MW-101, MW-102, MW-108 and MW-044) of the 12 wells sampled (Figure 8-22). Benzene accounted for three of the four exceedances, and was the only VOC detected in two of the three samples. MW-044 contained four VOC exceedances not including benzene. VOCs detected at MW-044 included 1,1-dichloroethene, 1,1,1-trichloroethane, tetrachloroethene and trichloroethene. MW-102 contained the highest concentration of benzene (1,700 µg/L) among the three wells with benzene exceedances. Table 8-19 summarizes the detection of volatile compounds exceeding the criteria in the first round of sampling.

Table 8-19 Central Yard First Round VOC Results

Compound (results in µg/L)	MW-044	MW-101	MW-102	MW-108
Benzene (Criterion = 1 µg/L)	NE	110	1,700	7
1,1-Dichloroethene (Criterion = 2 µg/L)	220	NE	9J	NE
1,1,1-Trichloroethane (Criterion = 30 µg/L)	2,100	NE		NE
Cyclohexane (Criterion = 100 µg/L)	NE	NE	170	NE

Table 8-19 Central Yard First Round VOC Results

Compound (results in µg/L)	MW-044	MW-101	MW-102	MW-108
Ethylbenzene (Criterion = 700 µg/L)	NE	NE	3,600	NE
Toluene (Criterion = 1,000 µg/L)	NE	NE	6,500	NE
Xylene (Criterion = 1,000 µg/L)	NE	NE	25,000	NE
Tetrachloroethene (Criterion = 1 µg/L)	37	NE		NE
Trichloroethene (Criterion = 1 µg/L)	34	NE		NE

NE = No Exceedance

SVOC Results

Four SVOCs (caprolactam, 2-methylnaphthalene, naphthalene and bis(2-ethylhexyl)phthalate) were detected in excess of the delineation criteria in three of the 12 wells sampled (Figure 8-24). Caprolactam was detected in both samples from MW-101 collected in the first round. 2-methylnaphthalene and naphthalene exceedances were detected in MW-102, and bis (2-ethylhexyl)phthalate was the only SVOC detected in MW-0044.

The phthalates detected in MW-44 are a common contaminant associated with sample handling procedures and are not evaluated further. Caprolactam is an additive used to make nylon rope; however, the Refinery has never been involved in this process. Nylon rope is used for sampling purposes at the Refinery. A segment of sampling rope was analyzed using an ASTM DI Leach test. The results indicated caprolactam in the leachate. Accordingly, Chevron believes the caprolactam in MW-101 to be a product of field sampling procedures. All SVOC exceedance results are presented in Table 8-20.

Table 8-20. Central Yard SVOC Exceedances

Compound (results in µg/L)	MW-0044		MW-101		MW-102	
	Round 1	Round 2	Round 1	Round 2	Round 1	Round 2
Caprolactam (Criterion = 100 µg/L)	NE	NE	110	250	NE	190
Bis(2-ethylhexyl)phthalate (Criterion = 30 µg/L)	91	NE	NE	NE	NE	NE
2-Methylnaphthalene (Criterion = 100 µg/L)	NE	NE	NE	NE	100	110
Naphthalene (Criterion = 300 µg/L)	NE	NE	NE	NE	550	540

NS Not sampled

NE Criterion not exceeded

Metals Results

A number of metals, including iron, manganese and sodium, were detected in excess of the delineation criteria in the majority of the wells in the Central Yard (Figure 8-25). The presence of these metals is attributed to the naturally-occurring clays that are found in the fill material and native soil. Chevron does not consider these analytes to be COCs and they will not be included in further evaluation of the Central Yard groundwater.

Eleven of the 12 wells were sampled and analyzed for metals. Metals exceedances were found in seven of the 11 wells. Arsenic, nickel and cobalt were the most common metals found in exceedance of the delineation criteria and were detected in three wells each:

- Arsenic (9 µg/L to 18.6 µg/L) was detected in wells MW-101, MW-102 and MW-103.
- Cobalt (153 µg/L to 548 µg/L) was detected in wells MW-101, MW-106 and MW-111.
- Nickel (162 µg/L to 190 µg/L) and was detected in wells MW-0044, MW-106 and MW-111.

Other exceedances included thallium in MW-111 and lead in MW-110. Metals results are presented in Table 8-21.

Tentatively Identified Compounds

All 12 of the wells sampled (13 samples) were analyzed for TICs during the first round (Table 8-22). Review of the TIC data indicated the presence of 4-hydroxy-4-methyl-2-pentanone in numerous samples. As discussed previously, this compound is a condensation product created in the laboratory through sample extraction procedures. Therefore this compound was eliminated from further evaluation.

TICs were found in seven of the 13 samples taken. Of these seven, three were associated with wells where benzene had been detected in excess of the criterion; therefore, no further specific evaluation was conducted on the TICs in these samples. Of the remaining four samples, MW-104 was the only well that had TICs exceeding the individual interim generic organic criteria for non-carcinogens of 100 µg/L with a single highest concentration of 350 µg/L. MW-104 also had a combined total of 877 µg/L, exceeding the 500 µg/L criteria. Table 8-23 presents TIC data for MW-104.

Table 8-21. Central Yard Metals Data (µg/L)

Well	Arsenic (Criterion = 8 µg/L)		Lead (Criterion = 10 µg/L)		Cadmium (Criterion = 4 µg/L)		Cobalt (Criterion = 100 µg/L)		Nickel (Criterion = 100 µg/L)		Thallium (Criterion = 10 µg/L)	
	Round 1	Round 2	Round 1	Round 2	Round 1	Round 2	Round 1	Round 2	Round 1	Round 2	Round 1	Round 2
MW-044	NE	NE	NE	NE	NE	NE	NE	NE	162	NE	NE	NE
MW-045	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
MW-101	18.6	14	NE	16J	NE	NE	548	NE	NE	NE	NE	NE
MW-102	9.7J	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
MW-103	9.1J	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
MW-104	NS	NE	NS	NE	NS	NE	NS	NE	NS	NE	NS	NE
MW-106	NE	8.2J	NE	NE	NE	NE	153	NE	170	NE	NE	NE
MW-106	NS	NE	NS	NE	NS	NE	NS	NE	NS	NE	NS	NE
MW-108	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	21
MW-110	NE	NE	11.3J	NE	NE	NE	NE	NE	NE	NE	NE	NE
MW-111	NE	NE	NE	NE	NE	NE	224	190	190	150	11.2J	70
MW-130	NE	8.5J	NE	28	NE	NE	NE	NE	NE	NE	NE	NE
MW-147	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
MW-167	NS	NE	NS	NE	NS	NE	NS	NE	NS	NE	NS	NE
MW-168	NS	NE	NS	NE	NS	NE	NS	NE	NS	NE	NS	NE
MW-169R	NS	NE	NS	NE	NS	NE	NS	NE	NS	NE	NS	NE
MW-169R	NS	NE	NS	NE	NS	NE	NS	NE	NS	NE	NS	NE
MW-170	NS	NE	NS	NE	NS	48	NS	NE	NS	390	NS	NE

Exceeds one or more criteria

NS Not sampled

NE Criterion not exceeded

Table 8-22. Central Yard Benzene and TIC Data (µg/L)

Well	Round 1							Round 2						
	Benzene	VOC TICs			SVOC TICs			Benzene	VOC TICs			SVOC TICs		
		No.	Single	Total	No.	Single	Total		No.	Single	Total	No.	Single	Total
MW-044	NE	3	10	21	14	34	157	NE	0	0	0	1	7	7
MW-045	NE	0	0	0	0	0	0	NE	0	0	0	0	0	0
MW-101	110	10	18	96	20	290	1,274	100	10	26	123	20	55	740
MW-101	NS	NS	NS	NS	20	150	895	NS	NS	NS	NS	NS	NS	NS
MW-102	1,700	9	3,800	12,700	20	3,200	9,233	170	11	910	2,415	20	1,300	7,159
MW-103	NE	9	50	205	20	90	430	NE	10	19	129	19	20	157
MW-104	NE	4	350	877	13	950	2,113	NE	4	150	344	8	420	871
MW-106	NE	0	0	0	4	7	22	NE	0	0	0	2	8	14
MW-106	NS	NS	NS	NS	NS	NS	NS	NE	0	0	0	6	48	83
MW-108	7	8	18	83	4	12	39	4J	3	7	18	7	10	39
MW-110	NE	0	0	0	1	4	4	NE	0	0	0	6	53	111
MW-111	NE	2	11	19	4	35	75	NE	0	0	0	6	32	64
MW-130	NE	0	0	0	0	0	0	NE	0	0	0	1	13	13
MW-147	NE	0	0	0	1	39	39	NE	0	0	0	2	10	14
MW-167	NS	NS	NS	NS	NS	NS	NS	NE	0	0	0	0	0	0
MW-168	NS	NS	NS	NS	NS	NS	NS	NE	0	0	0	0	0	0
MW-169R	NS	NS	NS	NS	NS	NS	NS	2J	3	10	24	0	0	0
MW-169R	NS	NS	NS	NS	NS	NS	NS	NE	0	0	0	0	0	0
MW-169R	NS	NS	NS	NS	NS	NS	NS	2J	1	10	10	NS	NS	NS
MW-170	NS	NS	NS	NS	NS	NS	NS	NE	0	0	0	1	5	5

Exceeds benzene criterion (1 µg/L)

Contains TICs that are unknown and exceed the interim generic standard for individual TICs (100 µg/L) or total TICs (500 µg/l)

NS Not sampled

NE Criterion not exceeded

Table 8-23. MW-104 VOC TIC Data

CAS Number	Compound	Retention Time (minutes)	Concentration (µg/L)
75-85-4	Amylene hydrate	7.82	350
590-36-3	2-Pentanol, 2-methyl	9.44	290
77-74-7	3-Pentanol, 3-methyl	9.74	180
1462-03-9	Cyclopentanol, 1-methyl	10.4	57
Total = 877			

A semi-volatile TIC analysis was conducted for all 13 samples collected. Of these, semi-volatile TICs were detected in 11 groundwater samples. Of those 11 samples:

- Three were from wells where benzene had been detected in excess of the criterion and were not examined further;
- Six had TICs that were below the interim criteria of 100 µg/L for individual non-carcinogenic organic compounds and 500 µg/L for total combined organic concentrations; and
- Two samples contained TICs that exceeded the generic individual organic criteria and the total combined organic criteria for non-carcinogens.

The two samples that contained TICs in excess of the interim generic standard include:

- **MW-101:** one unknown with a retention time of 29.227 minutes and concentration of 150 µg/L. The total combined concentration of 895 µg/L also exceeds the 500 µg/L criterion.
- **MW-104:** three TICs in excess of 100 µg/L and a total combined concentration of 2,113 µg/L, which is in excess of the 500 µg/L criterion. The two unknowns have retention times of 4.56 and 5.17 minutes.

Table 8-24 below details semi-volatile TICs for MW-104.

Table 8-24. MW-104 SVOC TIC Data

CAS Number	Compound	Retention Time (minutes)	Concentration (µg/L)
	Unknown	4.562	950
	Unknown	5.175	500
1462-03-9	Cyclopentanol, 1-methyl	6.291	520
	2-Hexanol, 2-methyl	7.289	10
	Unknown	7.645	34
	Unknown	8.099	6
590-67-0	1-Methylcyclohexanol	9.097	33
15466-94-1	Cyclohexanol, 1,3-dimethyl	10.243	7
	2-Cyclopenten-1-one, 3-methyl	10.638	6

Table 8-24. MW-104 SVOC TIC Data

CAS Number	Compound	Retention Time (minutes)	Concentration (µg/L)
	Unknown	11.469	6
	Unknown	17.998	14
	Unknown	21.991	22
	Unknown Alkane	32.989	5
			Total= 2,113

8.3.3.2 Contaminant Distribution- Second Round

Based on the assessment of the first round groundwater data, Chevron installed four additional wells in the Central Yard. A second round of groundwater sampling and analysis was conducted to confirm the results of the initial effort. The second round of sampling was conducted over the first six months of 2003. The sampling program included all of the wells sampled during the first round, and the newly installed wells MW-167, MW-168, MW-169R and MW-170 for a total of 16 wells. All 16 wells were analyzed for RFI parameters including VOCs, SVOCs and metals.

VOC Results

VOCs were detected above the delineation criteria in six of the 16 wells sampled (Figure 8-23). Benzene exceedances were detected in four of those 16 wells. Benzene was the only VOC detected above the criterion in two of the four wells demonstrating benzene exceedances. Two of the six wells, MW-0044 and MW-167, did not contain benzene exceedances. Wells indicating the presence of other VOCs in addition to benzene were MW-102 and MW-169R. Table 8-25 summarizes the detection of volatile compounds exceeding the criteria in the second round of sampling.

Three of the four wells with benzene detections in the second round were previously sampled in the first round. This data was used to confirm the presence of benzene in MW-101, MW-102 and MW-108. While the presence of benzene was confirmed in all three wells, all indicate decreasing benzene concentrations. Benzene was detected in concentrations exceeding the criterion in one new well (MW-169R) not previously sampled in the first round.

SVOC Results

SVOCs were detected in excess of the delineation criteria in one of the 16 wells sampled in the second round. The first round detections of bis(2-ethylhexyl)phthalate in MW-044 and caprolactam in MW-101 were not confirmed.

SVOCs were detected in MW-102 in the second round. The presence of 2-methylnaphthalene and naphthalene were confirmed in the second round of sampling.

Table 8-25. Central Yard Second Round VOC Results

Compound (results in µg/L)	MW-044	MW-101	MW-102	MW-108	MW-167	MW-169R		
Benzene (Criterion = 1 µg/L)	NE	100	1,600	4J	NE	2J	NE	2J
Ethylbenzene (Criterion = 700 µg/L)	NE	NE	3,000	NE	NE	NE	NE	NE
Toluene (Criterion = 1000 µg/L)	NE	NE	5,300	NE	NE	NE	NE	NE
Xylene (Criterion = 1000 µg/L)	NE	NE	20,000	NE	NE	NE	NE	NE
Cyclohexane (Criterion = 100 µg/L)	NE	NE	170	NE	NE	NE	NE	NE
1,1-Dichloroethene (Criterion = 2 µg/L)	160	NE	5J	NE	3J	130	9	150
1,1-Dichloroethane (Criterion = 70 µg/L)	NE	NE	NE	NE	75	NE	NE	NE
cis 1,2-Dichloroethene (Criterion = 10 µg/L)	NE	NE	NE	NE	NE	67	NE	88
1,1,1-Trichloroethane (Criterion = 30 µg/L)	1,000	NE	NE	NE	45	NE	NE	NE
Tetrachloroethene (Criterion = 1 µg/L)	14	NE	NE	NE	NE	2J	NE	2J
Trichloroethene (Criterion = 1 µg/L)	13	NE	NE	NE	NE	1,100	84	1,400
Vinyl chloride (Criterion = 5 µg/L)	NE	NE	NE	NE	NE	20	NE	21

NE = No exceedance

Caprolactam, which was not previously detected in the first round, was also present in the second round. All SVOC results are presented in Table 8-20.

Metals Results

The detection of metals at concentrations exceeding delineation criteria in the second round of sampling in the Central Yard was sporadic. Six of the 16 wells contained metals in excess of the criteria (Table 8-21). Of the six wells that were found to have exceedances, only two represent confirmation of results from the first round. The analytes most often encountered in concentrations exceeding criteria were arsenic followed by lead, thallium, cobalt and nickel.

- Arsenic (8.2 to 14 µg/L) was detected in three wells.
- Lead, thallium, cobalt and nickel were detected in two wells each.
- Lead was detected in MW-130 (16 µg/L) and MW-101 (28 µg/L). Lead was not previously detected in either of these wells during the first round of sampling.
- Thallium was detected in MW-108 (21 µg/L) and MW-111 (70 µg/L). Presence of thallium was confirmed by first round data in MW-111 only.
- Cobalt was detected in MW-101 (100 µg/L) and MW-111 (190 µg/L). Presence of cobalt was confirmed in the second round in both wells; however, the more recent data indicates lower concentrations.
- Nickel was detected in MW-111 (150 µg/L) and MW-170 (390 µg/L). Presence of nickel could only be confirmed in MW-111, because MW-170 is a newly installed well and, therefore, was only sampled in the second round.
- Cadmium was detected in excess of the criterion in MW-170.

Tentatively Identified Compounds

Groundwater from the 16 wells sampled in the Central Yard during the second round was analyzed for TICs. The compound 4-hydroxy-4-methyl-2-pentanone was not included in the TIC evaluation as it is a laboratory artifact.

Volatile TICs were detected in six of the 17 samples analyzed (Table 8-22). Of these six, four were associated with wells where benzene had been detected in excess of the delineation criteria; therefore, no specific evaluation was conducted. Of the remaining two samples, one sample from MW-104 had individual concentrations that exceeded the individual interim generic organic criteria of 100 µg/L for non-carcinogens. Table 8-26 below presents the volatile TIC data for MW-104.

Table 8-26. Second Round VOC TIC Data From MW-104

CAS Number	Compound	Retention Time (minutes)	Est. Concentration (µg/L)
75-85-4	Amylene hydrate	7.87	150
590-36-3	2-Methyl-2-pentanol	9.49	120
	Unknown	9.8	57
1462-03-9	1-Methylcyclopentanol	10.45	17
			Total= 344

Semi-volatile organic TICs were detected in 13 of the 17 samples analyzed. Of these, four were associated with wells where benzene had been detected in excess of the delineation criteria, so no further TIC specific evaluation was conducted. Of the remaining nine samples, only one from MW-104 had results exceeding the criteria for generic individual and total combined organic concentrations. Table 8-27 below presents semi-volatile TIC data from MW-104.

Table 8-27. Second Round SVOC TIC Data From MW-104

CAS Number	Compound	Retention Time (minutes)	Est. Concentration (µg/L)
	2-Methyl-2-pentanol	5.553	420
	Unknown	6.186	210
	1-Methylcyclopentanol	7.223	210
	4-(1,1,3,3-tetramethyl)phenol	8.349	5
	Unknown	8.428	5
	1-Methylcyclohexanol	9.583	10
	Unknown	32.47	5
	Unknown	36.773	6
			Total= 871

The samples from MW-104 are the only ones to contain semi-volatile TICs in excess of the interim generic standards in both rounds.

8.3.4 Data Analysis

Based on the two rounds of groundwater sampling and analysis conducted to date, Chevron has identified four areas impacted by dissolved phase constituents in the Central Yard groundwater. Three of these plumes (SWMU 15, CY2 and AOC 25) are found in the northern and central portion of the Yard and are defined by low concentrations of benzene. No other VOCs or SVOCs have been detected above the criteria in these three plumes. The fourth plume (AOCs 22 and 36) is in the southern portion of the facility and is characterized by higher concentrations of benzene along with chlorinated organic compounds and some SVOCs. For the first three plumes, the assessment of groundwater is focused on benzene, as it is the only consistent COC detected. For the AOC 22/AOC 36 plume, the assessment involves the presence of BTEX and chlorinated compounds.

When the chlorinated compounds were detected and it became apparent that they originated from a source different than the BTEX compounds, AOC 36 – Chlorinated Hydrocarbons in Groundwater was established. Although the areas impacted by the dissolved BTEX and chlorinated compounds overlap, the characteristics of these compounds are sufficiently different that the delineation of each is described separately.

8.3.4.1 SWMU 15

SWMU 15 is located in the southern portion of Tank Basin 14 (Figure 8-22). The investigation was prompted by a Refinery drawing that indicated this area may have been used for the disposal of leaded gasoline sludge. While there is limited evidence that this area was used in this manner, there is evidence of low-level petroleum impacts in both the soil and groundwater. The boring log for S0741 indicated a petroleum odor at a depth of approximately four feet. Additionally, in one soil sample, a slight exceedance of the benzene standard of 1 mg/kg was detected. MW-108 was constructed at the location of S0741 with 10 feet of well screened across the shallow water bearing zone.

Benzene exceedances were detected in both rounds of sampling at MW-108 (7 µg/L in the fourth quarter of 2002 and an estimated 4 µg/L in the first half of 2003). No other VOCs or SVOCs were detected in excess of the delineation criteria.

The groundwater elevation data indicates flow in the vicinity of MW-108 approximates a radial pattern with a tendency towards a northwesterly flow. Gradients are fairly low. To the north and west, gradients approximate 0.02 ft/ft; to the south and east, gradients are significantly below 0.01 ft/ft. The fill material and the native soils in this area are characterized as stiff gray clay with minor amounts of sand and silt to a depth of more than 20 feet. The combination of low gradients and low hydraulic conductivities associated with the clays found in this area result in very low groundwater velocities.

Using a conservative estimate for hydraulic conductivity and published values for effective porosity for the clays indicated on the boring logs, a groundwater velocity has been calculated as follows:

$$Velocity = \frac{Hydraulic\ Conductivity \times Gradient}{Porosity_{(effective)}}$$

$$Velocity = \frac{(1 \times 10^{-4} \text{ cm/sec}) \times (0.01)}{0.15}$$

$$Seepage\ Velocity \approx 7 \text{ ft/yr}$$

The benzene detected in MW-108 is delineated to the west and south by numerous groundwater samples collected from temporary well points and MW-106. Delineation to the north is provided by MW-111. Chevron is proposing to monitor the three wells in this area for an additional six sampling events to determine whether there is an ongoing source of benzene, or if the benzene concentrations are declining. The wells to be sampled include MW-106, MW-108 and MW-111. Groundwater samples will be analyzed for volatile compounds only.

Also in this area, three metals (cobalt, nickel and thallium) have been detected in groundwater in excess of the criteria through two rounds of groundwater sampling in MW-111. A review of the field sampling data indicates a pH of 3.0 in the groundwater in the vicinity of MW-111. The field data also indicates a pH of about 4.8 for MW-108. The low pH is likely the reason for the detection of metals in MW-111; however, the source of the low pH is unknown. The boring logs do not indicate unusual fill materials or other causes for the low pH. The groundwater affected by the low pH appears to be limited. MW-106, once purged, has a pH in the 7.3 range and MW-110 has a pH of about 6.4. Chevron will continue to monitor pH conditions in this area as part of the monitoring conducted for SWMU 15.

8.3.4.2 AOC 25

AOC 25 is associated with an LNAPL plume that was originally identified during the OWSS Phase II investigation. It is located in the northwestern corner of the Central Yard (Figure 8-22). Since it was discovered, the LNAPL has been delineated and recovery efforts are underway (see Section 7.10). The boring logs in this area indicate approximately 12 to 15 feet of fill material overlying the native gray clay. The fill material is composed primarily of silty material with substantial amounts of sand. The native material is very similar in description to the clay found near SWMU 15. (i.e., Clay Horizon A). Groundwater flow is to the north with an hydraulic gradient of 0.023 ft/ft as measured between MW-147 and TPM3732.

As part of the Phase II OWSS Investigation, an arc of groundwater samples were collected along the northern edge of the Central Yard (H0519 through H0522). These samples are downgradient of AOC 25. Benzene was detected in only one sample at concentrations that exceed the criterion (H0519 at 16 µg/L). More recently, as part of the LNAPL investigation, an additional groundwater sample (H0837) was collected near H0519 and downgradient of AOC 25. No VOCs or SVOCs were detected in excess of criteria.

Given the description of the fill material as silts and sands and the steeper gradient of the groundwater table in this area, the potential for more extensive migration of dissolved constituents from this AOC was examined. The groundwater results from the two nearest wells in the Main Yard, MW-154 and MW-138, did not indicate the presence of VOCs or SVOCs.

In summary, there is no evidence that a significant area impacted by dissolved phase constituents associated with AOC 25 LNAPL exists. As the LNAPL recovery efforts near completion, Chevron proposes to collect two rounds of groundwater samples from recovery wells that have not exhibited LNAPL for a period of three months. Further, two additional samples will be collected at the same time from upgradient well MW-147 and the downgradient temporary well point TPM3732.

8.3.4.3 Area CY2

This area is located in the northeastern portion of the Central Yard (Figure 8-22). The tanks in this area historically managed crude oil and No. 2 fuel oil. The initial investigation of this area was prompted by a Refinery drawing that indicated plans to use certain areas for the disposal of leaded gasoline sludge through burial. Subsequently, several groundwater samples were collected as part of the OWSS Phase II Investigation, and finally, one groundwater sample was collected as part of the PAOC Investigation. The data collected from these various investigations indicate that an area exists containing a low concentration of dissolved phase benzene. In response to this finding, the initial effort of the RFI included the installation of three additional wells screened in the shallow water table (MW-103, MW-104 and MW-130) to determine the overall condition of the groundwater in this area. All three wells were sampled twice, once during the fourth quarter of 2002 and once during the first half of 2003. No VOCs or SVOCs were detected in any of the three wells in either round of sampling.

The dissolved phase plume has been delineated using existing data, the new data from the three wells and MW-105 (located in the State Street Parking Lot to the east), and the area impacted by the dissolved phase benzene has been delineated. H0550, H0551, H0285, H0282, H0284, MW-104 and MW130 combined represent the clean zone downgradient of the dissolved phase constituents. MW-103 monitors groundwater conditions upgradient of the plume.

The boring logs from this area indicate eight to ten feet of fill overlying the native material. The fill is described as silts, sands and clays. The description of the native material varies from light gray sands and dark gray clays to reddish clays and sands. The reddish material indicates the presence of till while the gray clay and sand could indicate the northern edge of the Clay Horizon A marine deposits. The groundwater flow direction is to the northeast and the gradient approaches 0.02 ft/ft as measured between MW-103 and MW-130.

Using site specific estimates for hydraulic conductivity and published values for effective porosity for the geologic conditions indicated on the boring logs, an estimated groundwater velocity has been calculated as follows:

$$Velocity = \frac{Hydraulic\ Conductivity \times Gradient}{Porosity_{(effective)}}$$

$$Velocity = \frac{(1 \times 10^{-4} \text{ cm/sec}) \times (0.02)}{0.15} \qquad \text{Seepage Velocity} \approx 15 \text{ ft/yr}$$

Given the low concentrations of benzene previously detected and the lack of detections in the existing monitoring wells, Chevron concludes this plume is limited in extent and probably decreasing in size. Therefore, Chevron proposes continued monitoring of existing wells MW-103, MW-104, MW-130 and MW-105 on an annual basis for a period

of two years to determine the migration potential of the dissolved phase benzene. Groundwater samples will be analyzed for VOCs, SVOCs and metals.

8.3.4.4 AOC 22

AOC 22 was initially identified during the 1st-Phase RFI for groundwater when BTEX constituents were detected in HP-0014. The sample was collected in close proximity to the site of a removed UST and pump island that had managed gasoline for Refinery vehicles. During removal of the UST, it was noted that there were no holes or any evidence of a release from the tank; however, there were petroleum impacted soils that required disposal. HP-0014 was installed to determine if there were impacts to groundwater. With the disposal of the UST and impacted soils, the source of the groundwater impact has been removed.

In 1998, MW-44, MW-45 and MW-46 were installed to determine groundwater flow conditions in the Central Yard. Based on the depth and type of fill material encountered during the installation of MW-44, it appears it was installed in the actual UST excavation. Since the wells were installed only for water level information, it was not sampled. The data collected from the three wells did indicate that there was a more complex groundwater flow regime in the Central Yard than previously thought. With the limited data, it appeared groundwater flow from the Shops Building to the Garretson Avenue right-of-way was to the south, while flow from MW-45 to the Garretson Avenue right-of-way is to the north. Groundwater flow in the northern portion of the Central Yard is to the north-northeast.

The initial RFI effort in this area was directed towards delineation of the dissolved BTEX compounds in the groundwater (Figures 8-22 and 8-23). To accomplish the delineation, two wells (MW-101 and MW-102) and four temporary well points (H0870, H0872, H0873 and H0892) were installed. Groundwater samples were collected from each of these locations and from existing wells MW-44 and MW-45. The results from H0892, MW-44 and MW-102 indicated that in addition to the BTEX compounds, it would be necessary to further investigate several chlorinated compounds that were detected.

When the chlorinated compounds were detected and it became apparent that they originated from a source different than the BTEX compounds, AOC 36 was established. Although the areas impacted by the dissolved BTEX and chlorinated compounds overlap, the characteristics of these compounds are sufficiently different that the delineation of each is described separately.

As part of the second phase of the RFI, Chevron added four additional wells to delineate the COCs. These wells included three shallow wells and one deeper well. Three of the wells (MW-167, MW168 and MW-170) are screened in the shallow water table in the fill. MW-169R is screened from 15 to 25 feet bgs across a sandy zone. This sand is described as reddish brown and is the stratigraphic equivalent of Sand Horizon A. By its color, this sand appears to be glacial in origin. In the second round of groundwater sampling, the previous detections of both BTEX and chlorinated compounds were

confirmed. In addition, chlorinated compounds were detected in excess of the criteria in MW-167 and MW-169R. No VOCs or SVOCs were detected in excess of the criteria in MW-170 or MW-168.

Petroleum Plume (AOC 22)

Since no BTEX exceedances were detected in MW-44, it appears the original source is the gasoline dispensing system that has been removed. BTEX compounds were also detected in H0892 and MW-101; however, benzene was the only BTEX compound that exceeded the criterion in either of these samples. Further horizontal delineation of this plume is provided by H0870, H0873, MW-168 and MW-170 (all screened in the shallow water bearing zone), in which no volatile compounds were detected in excess of the criteria. Vertical delineation is provided by MW-169R, screened across the fill/native interface and into the first water bearing zone beneath the fill. While chlorinated compounds were detected in this well, BTEX compounds were not.

In summary, it appears the dissolved BTEX compounds originated in the vicinity of the removed UST system and has migrated to the south southeast. The shape of this plume appears to be controlled by groundwater flow to the south-southeast, turning more easterly in the area of the Garretson Avenue right-of way. There is still no direct evidence that this plume has migrated off-site. To determine if this is the case, Chevron will install one additional shallow well nested with MW-169R on the eastern property boundary. This well, along with MW-168, MW-170, MW-101, MW-102 and MW-44 will be sampled for an additional six periods to determine constituent trends. Samples will be analyzed for VOCs and SVOCs. If BTEX compounds are detected in the shallow nested well, they will be included in the off-site investigation that is proposed for the chlorinated compounds.

Chlorinated Organic Plume (AOC 36)

The groundwater impacted by dissolved chlorinated compounds was first detected when MW-044 was sampled on October 22, 2002 during the initial stages of the RFI. Since then, several wells have been installed in the vicinity of MW-044, and a separate investigation has been conducted to evaluate the chlorinated organic plume. The separate investigation was conducted by Hayworth Engineering Science, Inc. (HES). HES utilized a cone penetrometer for soils identification and a geoprobe with a membrane interface probe to detect volatile organic constituents. The results of the investigation are presented in Appendix K of this report.

In summary, it appears the source of the chlorinated compounds is located upgradient of MW-44 near the Shops Building. Groundwater in this area flows towards the south-southeast. Groundwater near MW-044 is perched on the stiff, grey, marine, native clay described as Clay Horizon A. This clay appears to have restricted the vertical migration of the chlorinated organic compounds. Further to the south however, the clay gives way to remnant glacial deposits that slope steeply to the south. In the vicinity of MW-168 and MW-169R, it appears that the fill may be in contact with Sand Horizon A.

The HES investigation provides additional data on the chlorinated organic plume. The shape of the plume closely resembles the BTEX plume previously discussed. The two plumes appear to be commingled in the vicinity of MW-102, but also appear to be vertically separate in the southern limits of the plume. The chlorinated compounds extend into Sand Horizon A, while benzene has remained in the shallow water table that is found in the fill material. Chevron intends to add two wells to the onsite monitoring system including a well nested with MW-101 that is screened in Sand Horizon A and a shallow well upgradient of the expected point of release of the chlorinated compounds.

Chevron also intends to conduct additional investigations to determine if the chlorinated organic plume extends off-site. One east-west and two north-south transects are planned, utilizing the field screening technology supplied by HES, Inc. The actual location of these transects will be controlled to a large extent by Chevron's ability to gain access to various properties and by multiple underground utilities that run along State Street. Results of this offsite investigation will be supplied to the USEPA and the NJDEP by way of an addendum to this RFI Report. Chevron will also continue to monitor the concentrations of chlorinated compounds onsite by sampling the seven existing wells and the two proposed wells for a minimum six additional rounds. The samples will be analyzed for VOCs.

A list of all monitoring wells to be resampled throughout the Refinery is presented in Table 8-28 below:

Table 8-28. Wells to be Resampled

Well	VOC Analysis	SVOC Analysis	Metals Analysis
East Yard			
A21TP1	X		
A21TP1	X		
MW-7	X		X
MW-8	X		
MW-9	X		X
MW-10	X		
MW-14	X		
MW-35	X		
MW-43	X		
MW-51	X		
MW-73	X		
MW-90	X		X
MW-129		X	X
MW-131	X	X	
MW-132	X	X	X
MW-134	X		

Table 8-28. Wells to be Resampled

Well	VOC Analysis	SVOC Analysis	Metals Analysis
MW-135	X		
MW-141	X		
MW-142	X		
MW-143	X		X
MW-144	X		X
MW-145	X		
MW-146	X	X	X
MW-148	X		
MW-149	X		X
MW-151	X		
MW-152	X		X
MW-153	X		
MW-155	X		
MW-156	X	X	
MW-157	X		X
MW-158	X		
MW-171	X		X
MW-173	X		X
MW-174	X		X
MW-175	X		X
MW-178			X
RW-61	X		
SB-14	X		
SB-15	X		
Central Yard			
MW-44	X	X	
MW-101	X	X	X
MW-102	X	X	X
MW-103			X
MW-106			X
MW-108	X		
MW-110			X
MW-111			X
MW-130			X
MW-167	X		
MW-169R	X		
MW-170			X

Table 8-28. Wells to be Resampled

Well	VOC Analysis	SVOC Analysis	Metals Analysis
North Field/Main Yard			
MW-3			X
MW-12			X
MW-13			X
MW-20			X
MW-21		X	
MW-32			X
MW-33			X
MW-39	X		
MW-65	X	X	
MW-117	X	X	X
MW-118	X		X
MW-120			X
MW-121	X	X	X
MW-122	X		X
MW-123	X	X	X
MW-124			X
MW-125	X		
MW-133	X		
MW-137			X
MW-139			X
MW-154			X
MW-159			X
MW-165	X		
MW-179	X		X
MW-180	X	X	X
NF-10	X		
NF-11	X		
NF-12		X	
NF-13			X
NF-16			X
P-2			X
P-4			X
P-5			X
RW-42	X		